

# The Effect of Hospital Closures on Maternal and Infant Health\*

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## Abstract

In recent years, many hospitals have eliminated maternity care, a low-profit service. I estimate the impact of rural hospital maternity ward closures on birth outcomes in the United States using national Vital Statistics data. On the one hand, increased travel distance following closure can lead to decreased utilization of prenatal care or an increase in out-of-hospital births. On the other hand, women may be exposed to providers with better practices. Rural closures appear to create benefits: I find a large decline in Cesarean births for low-risk women alongside precise null effects for infant outcomes, suggesting closure hospitals were over-performing Cesareans.

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Since the early 2000s, hundreds of hospitals have closed or are at risk of closing. Moreover, when hospitals are financially strained, they may eliminate their least profitable services. Maternity care is often one of the first services to be eliminated due to high costs and low reimbursements. As a result, nine percent of counties lost maternity services between 2004 and 2014 ([Hung et al. \(2017\)](#)) and today almost half of counties have low or no access to maternity care ([March of Dimes \(2020\)](#)). The increase in maternity ward closures has raised concerns about access to care, increased travel distances, and growing health disparities.<sup>1,2</sup>

In this paper, I study the impacts of rural maternity ward closures on the health outcomes of women and infants. Depending on the context, maternity ward closures may have either positive or negative effects on maternal health. On the one hand, increased travel distances may generate adverse health consequences. Large increases in travel distance could increase out-of-hospital births and decrease utilization of prenatal care. To avoid the uncertainty of traveling the increased distance while in labor, women may prefer to schedule an induction. Any decline in maternity ward access is especially concerning in the U.S. context, given levels of infant and maternal mortality as well as Cesarean rates well in excess of levels in other rich countries ([OECD \(2019\)](#)).

On the other hand, the closure of maternity wards could improve health outcomes. When a maternity ward closes, women are shifted to other hospitals and exposed to the delivery practices and resources of that hospital. Delivery practices vary greatly between hospitals, with Cesarean delivery rates ranging from 19 percent to 48 percent across hospitals ([Card et al. \(2019\)](#)). If the closure hospital is of lower quality, the benefits of shifting to an

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<sup>1</sup>Several bills aimed at increasing access to maternal healthcare have been presented to Congress. For a brief description of bills introduced in 2019 and 2020, see <https://www.kff.org/womens-health-policy/factsheet/analysis-of-federal-bills-to-strengthen-maternal-health-care/>

<sup>2</sup>Several recent articles have highlighted the concerns regarding maternity ward closures. For a few examples, see <https://www.nytimes.com/2020/05/05/parenting/coronavirus-black-maternal-mortality.html>, <https://www.usnews.com/news/healthiest-communities/articles/2019-06-13/what-happens-when-rural-communities-lose-their-hospital-maternity-care>, and <https://www.npr.org/sections/health-shots/2016/02/24/467848568/more-rural-hospitals-are-closing-their-maternity-units>.

alternative hospital may outweigh the costs of reduced access to local care.

Since maternal mortality is rare in rich countries, Cesareans can be used as a metric of how maternity ward closures impact maternal health. The American College of Obstetricians and Gynecologists (ACOG) highlights that the rapid increase in Cesarean births without a concurrent increase in maternal or fetal morbidities suggests that Cesarean births may be overutilized in the United States. ACOG provides guidelines for doctors to reduce primary Cesarean births. The guidelines highlight that for most pregnancies, Cesarean delivery, a major abdominal surgery, carries a greater risk of maternal morbidity and mortality than vaginal delivery ([ACOG \(2014\)](#)). Thus, if the Cesarean rate rises without an underlying justification (e.g., improvements in infant health or an increase in the Cesarean rate among high-risk women), this suggests more women are exposed to an increased risk of maternal morbidities without any clear benefits. Likewise, if the Cesarean rate falls without any subsequent harms (e.g., infant health is no worse off and high-risk mothers still receive Cesareans), it suggests fewer women are unnecessarily exposed to a risk factor of maternal morbidities.

To study the relationship between rural maternity ward closures and birth outcomes, I use national birth certificate records from the National Center for Health Statistics (NCHS) from 1996 to 2018. These data provide the universe of births, with rich details on characteristics of the pregnancy, labor, and birth outcomes. The restricted-access files contain additional information on county of residence and county of birth, allowing me to precisely identify when a woman's residence county loses access to maternity care. Using this information, I identify counties that go from having a hospital with a maternity ward to having no hospitals with a maternity ward, an event that is mostly concentrated in rural areas.

To quantify how rural maternity ward closures affect women and infants, I adopt a matched difference-in-differences approach exploiting variation in the timing of closures, defined as the year when a county loses all maternity services. Using detailed demographic and economic characteristics at the county level, I construct a matching algorithm to find a

set of counties that do not lose maternity services to form a control group. I then compare the evolution of health outcomes for women and infants in treated and comparison counties around the time of the maternity ward closure. My results are robust to a non-matching strategy using recent advancements in the difference-in-differences literature from [Callaway and Sant'Anna \(2021\)](#).

I do not find any evidence of adverse impacts on infant health outcomes. I can rule out relatively small deleterious effects on low birth weight, Apgar scores, and preterm birth, rejecting increases in low birth weight of more than 1.3 percent, increases in the share of births with an Apgar score below 7 of more than 8.3 percent, and increases in preterm birth of more than 0.5 percent.<sup>3</sup> While I cannot rule out small increases in infant mortality due to a small baseline mortality rate, the precisely estimated zero effects on other infant health outcomes provide reassuring evidence that maternity ward closures do not harm infants.

Likewise, I do not find evidence that rural maternity ward closures harm maternal health—if anything, birth outcomes appear to improve. I find that women residing in counties that experience a maternity ward closure have significant *reductions* in Cesarean births relative to the matched control counties. Further, I find support for the idea that local provider practice plays an important role in the health impact of maternity ward closures. The reduction in Cesarean births is concentrated among women who move to providers with a lower propensity to perform a Cesarean following closure.

The reduction in Cesarean deliveries is driven by women with low medical risk factors. Because Cesarean births are major abdominal surgeries and are associated with increased risk of maternal morbidity, they should be reserved for women who are unable to have a safe and healthy vaginal delivery. I show that maternity ward closures are associated with lower rates of Cesarean births for women predicted to be at low-risk for complications, calculated as a function of age and other medical attributes, and no changes in rates for high-risk

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<sup>3</sup>The Apgar score assesses a newborn's color, heart rate, reflexes, muscle tone, and respiration. Scored out of 10, a score of 7 or more is considered "reassuring," while scores below 7 are considered abnormal.

women, suggesting that women benefit from the new providers.

This paper contributes to the expansive literature studying maternal and infant health. Several papers study how policies and environments impact health outcomes ([Aizer et al. \(2007\)](#), [Almond et al. \(2011\)](#), [Almond et al. \(2012\)](#), [Evans and Garthwaite \(2014\)](#), [Chen et al. \(2016\)](#), and [Kuziemko et al. \(2018\)](#)). Others investigate the impact of access to hospitals and clinics on utilization of care ([Currie and Reagan \(2003\)](#) and [Lu and Slusky \(2016\)](#)). I complement this literature by documenting how access to hospital-based maternity services in a woman's local area impacts birth outcomes.

In addition, this paper is related to the literature on Cesarean birth. [Currie and MacLeod \(2017\)](#) find that improved decision making among providers could reduce Cesarean births for low-risk women. Other papers study the health impacts of Cesarean deliveries, often finding an association between Cesarean birth and respiratory issues ([Costa-Ramón et al. \(2018\)](#), [Costa-Ramón et al. \(2020\)](#), and [Card et al. \(2019\)](#)). In my paper, I document a strong reduction in Cesarean deliveries concentrated among low-risk women. I provide suggestive evidence that this reduction is a result of provider practices, suggesting the delivery patterns of the doctor at birth plays an important role in determining the mode of delivery following maternity ward closures in rural areas.

Several papers have studied the relationship between maternity ward closures and birth outcomes ([Lorch et al. \(2013\)](#), [Avdic et al. \(2018\)](#), [Hung et al. \(2018\)](#), [Hussung \(2018\)](#), and [Kozhimannil et al. \(2018\)](#)). The results in this literature are mixed, with some papers finding adverse effects while others find no effect or even positive effects. [Avdic et al. \(2018\)](#), studies maternity ward closures in Sweden using an experimental design and finds adverse effects on maternal health but improvements in fetal health. [Kozhimannil et al. \(2018\)](#) uses an interrupted time series design and finds women in rural counties not adjacent to urban areas see increases in out-of-hospital birth, births in hospitals without an obstetric unit, and preterm birth. I focus on a longer time frame and utilize an alternative empirical strategy. In addition, I investigate effects by maternal risk factors and provider practice

styles. Finally, I also explore potential spillover effects and heterogeneity across types of women. In a concurrent working paper, [Fischer et al. \(2022\)](#) analyze the health impacts of rural maternity ward closures. Similarly to this paper, [Fischer et al. \(2022\)](#) find no evidence of negative health impacts on infant health and reductions in Cesarean birth.

The rest of the paper is organized as follows. Section 1 describes the data sources I use, and Section 2 discusses how maternity ward closures could impact health outcomes. In Section 3 I discuss my research design and estimation strategy. Section 4 presents the baseline results. Sections 5 and 6 present additional results on the baseline findings and Section 7 concludes.

# 1 Data

## 1.1 Birth Certificate Data

The main analysis in this paper utilizes the U.S. Cohort Linked Birth/Infant Death Data Files provided by the National Center for Health Statistics (NCHS) for the years 1996 through 2018 ([National Center for Health Statistics \(2018\)](#)).<sup>4</sup> The vital statistics data contain information on maternal and infant socio-demographic characteristics such as race, ethnicity, education, and age. The data also contain details of the pregnancy and birth, including prenatal care, health risk factors, complications, and method of delivery. Maternal health outcomes are limited in the birth certificate data. Some measures of Severe Maternal Morbidity were added in the 2003 revision and states adopted the revised certificate over the next several years. Due to the limited information, this paper focuses on prenatal care, induction, and cesarean birth as measures of maternal health. Information on the infant's health, such as gestational age, birth weight in grams, and mortality within one year of birth, are also available in the data. In addition, I have access to the restricted-access files, which contain

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<sup>4</sup>Cohort-linked birth and death certificates were not created for 2003 and 2004. The data for 2003 and 2004 are from the U.S. Natality Detail Files ([National Center for Health Statistics \(2004\)](#)).

relevant geographic information, including women’s county of residence and county where the birth occurs.

In the NCHS data, I identify when a county experiences a “complete” loss of maternity services. I classify a county as having lost all maternity services if the county observes a drastic reduction in hospital births. I count the total number of hospital births occurring in a county in a given year and calculate 3-year averages. A county “loses services” in year  $n$  if the 3-year average in years  $n - 1$ ,  $n - 2$ , and  $n - 3$  is more than 15 hospital births while the 3-year average in years  $n$ ,  $n + 1$ , and  $n + 2$  is less than 5 hospital births. Importantly, this method does not identify counties that have other providers of maternity care after a hospital closes its maternity ward. Since most urban counties have more than one hospital providing maternity care, this method mostly identifies rural counties. Figure 1 displays the number of counties offering maternity care through time. The number of counties losing services is fairly consistent across years, with around 16 closures each year.

This method of identifying closures is an improvement over prior work that relies on the American Hospital Association’s Annual Survey. The AHA Annual Survey includes a hospital’s self-report on information that can be used to infer offering maternity services, such as the number of births, obstetric beds, and bassinets. However, relying on only the AHA Annual Survey could lead to inaccuracies in identifying closures. With a response rate of around 80 percent, it can be challenging to precisely identify the year of a maternity ward closure if a hospital doesn’t respond in the years surrounding a closure. More importantly, hospitals can appear to “drop out” of the survey as a result of hospital consolidations and mergers. In many cases, only the parent hospital reports data to the AHA Annual Survey. Following a merger, it becomes increasingly challenging to identify a closure based on the Annual Survey. The birth certificate records, on the other hand, provide an administrative count of the number of hospital births in a county. This allows for the date of closure to be precisely and accurately identified, with the tradeoff being the inability to observe intensive margin changes within a county.

Figure 2 plots the average number of births in a county around the year of closure. The average number of births leading up to a closure is around 160 births per year. There is a significant drop in the number of births in the year prior to closure due to closures occurring at various points in calendar time. Upon closure, births in treated counties drop to zero, confirming a large “first stage.” Though births drop dramatically in treatment counties, a county that closes its maternity ward could still see a small number of births post-closure due to isolated events. In particular, a woman may show up to the emergency room to deliver in a hospital that does not typically provide maternity services or a woman may (intentionally or unintentionally) give birth out of a hospital within the county.

### 1.1.1 Characteristics of the Sample

Table 1 reports summary statistics for various groups in the NCHS data. Column 1 presents summary statistics for counties that close their maternity ward at any point between 1996 and 2018 ( $N = 391$ ), Column 2 presents summary statistics for counties without any maternity services from 1996 through 2018 ( $N = 1,150$ ), and Column 3 presents summary statistics for counties providing maternity services continuously from 1996 to 2018 ( $N = 1,591$ ). Counties that experience a closure have a smaller population than counties that provide maternity services continuously, but are larger than counties that never offered maternity services during the sample period. The closure counties are generally small and rural, with an average population of around 22,000. Relative to the counties that always had maternity services, counties that lose services or never had services have fewer women of childbearing age, a higher share Black, and a lower share of college completion. In addition, the unemployment rate is higher and the county has fewer establishments. In Appendix Table A1, I show the hospitals that close tend to be smaller, as measured by the number of births and the number of beds, as well as tend to provide less specialized birthing care, as measured by the presence of a neonatal intensive care unit (NICU).

## 1.2 Other Data

I utilize additional sources of data to augment my analysis. I make use of County Business Patterns to obtain the number of establishments in a county in 1995. In addition, I obtain county-level population, per capita income, and per capita transfers in 1995 from the BEAs Regional Economic Information System. I use the BLS's Local Area Unemployment Statistics to obtain the unemployment rate in 1995. Finally, I utilize Census data to obtain information on education levels and demographic characteristics.

## 2 Background on Maternity Ward Closures

Providing labor and delivery services is expensive, requiring low patient-to-nurse ratios and access to surgical and monitoring equipment. In addition, reimbursements rates are often low since Medicaid covers a significant portion of births. The combination of high costs and low reimbursements has led some financially-strained hospitals to close their maternity wards. These closures can impact health outcomes through several channels, including changes in distance, changes in quality, and spillovers in surrounding areas. Figure 3 highlights the potential channels through which maternity ward closures can impact health outcomes in rural areas.

Women whose local maternity ward closes (“closure women”) will have a change in the travel distance to the nearest hospital with a maternity ward. The increase in travel distance could negatively impact health outcomes if the increase results in more out-of-hospital births. In the United States out-of-hospital birth is more dangerous and results in higher mortality compared to hospital birth ([Grünebaum et al. \(2020\)](#)). In addition, some women may experience reduced access to prenatal care in their county of residence if maternity ward closures lead to obstetricians leaving the area or if prenatal care was provided in the hospital. This could lead to longer travel distances for prenatal care, potentially decreasing women’s utilization of prenatal care. Regular prenatal care can identify potential obstetric complications,

and pregnancies with no or limited prenatal care are associated with increased morbidity and mortality (Moore et al. (1986), Twizer et al. (2001), and Vintzileos et al. (2002)). Increased travel distance could also impact the procedures performed during the birth. In particular, women and/or providers may schedule inductions in order to minimize uncertainty regarding traveling far distances while in labor. An increase in inductions could result in an increase in Cesareans via the “cascade of interventions,” where more medical interventions are performed following an induction, ultimately resulting in a Cesarean (Lewis et al. (2019)). The impact of travel distance is likely to be large for rural closures. The average travel distance to a maternity ward following closure for a woman in a rural area in my sample is more than 30 miles.

In addition to the change in travel distance, there may also be a change in the quality of the closest hospital. Women may be exposed to higher-quality hospitals and providers if the hospital that closes its maternity ward is of lower quality. For rural women, the potential quality improvements may be large. The hospital data from the AHA Annual Survey, summarized in Table A1, suggests that rural hospitals are small and do not provide advanced neonatal care. In particular, no rural hospital that closed its maternity ward had a Neonatal ICU. In addition, the number of births in rural hospitals is relatively small, with only around 150 births per year prior to closure. If there is “learning by doing” in maternity care, the doctors in rural areas will be less experienced than those in areas that oversee more births.<sup>5</sup>

In addition to the closure women, there could potentially be spillover effects on the women at the hospitals where the closure women go (“receiving women”). If the closure women create a strain on the surrounding hospitals, there could be decreases in the quality of care for receiving women. The impact of spillovers is likely small for rural closure. With only 150 births per year prior to closure, these women may easily find beds in surrounding

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<sup>5</sup>Several papers have studied “learning by doing” in medical care, though none have focused on maternity care. See Bridgewater et al. (2004), Contreras et al. (2011), Halm et al. (2002), and Vickers et al. (2007) for examples.

areas without much impact. This section highlights that, for rural closures, most impacts are likely to be concentrated among the closure women, with competing positive and negative forces, while receiving women are unlikely to be impacted.

## 3 Empirical Strategy

The goal of this study is to estimate the reduced-form impact of losing access to hospital-based maternity services on health outcomes of women and their newborns. To assess the impact of losing hospital-based maternity services, I employ a matched difference-in-differences design. Counties that offer hospital-based maternity services in 1996 and lose those services between 2002 and 2012 (and do not re-gain those services) serve as the treated counties in the analysis. Counties that continually provide maternity services from 1996 to 2018 serve as the potential control group.

### 3.1 Matching Procedure

I implement a matching procedure to generate balance along observable characteristics between treatment and control areas. To be eligible for inclusion in the matching procedure, treatment counties must experience a closure of hospital-based maternity services between 2002 and 2012. As the baseline specification will incorporate a six year analysis window, counties that lose services outside of the 2002 to 2012 range are not included in the analysis. Potential control counties must have continual services from 1996 to 2018. Counties that never provide maternity services from 1996 to 2018 cannot serve as a control in the baseline analysis and are excluded from the matching procedure. I utilize this group as an additional control in the Appendix.

I use a parsimonious set of characteristics to match each treated county to a counterfactual control county. Treated counties are matched to non-adjacent counties within the same state. It is important to match within the same state as many health policy decisions (e.g.

Medicaid/Medicare policies and medical malpractice laws) occur at the state level and these policies can impact pregnancy and birth outcomes ([Aizer et al. \(2007\)](#), [Currie and MacLeod \(2008\)](#), and [Kuziemko et al. \(2018\)](#)). Within state matching ensures treatment and control counties are similar along observable characteristics and experience the same broader health policy environment. However, allowing for unrestricted matching within the state would be problematic as it could create a treatment-control pair that are geographic neighbors. The control could then be impacted by the closure through potential spillover effects. Matches are restricted to be nonadjacent counties to avoid control county contamination.

I use propensity score matching and match based on population, number of establishments, unemployment rate, median household income and transfers, percent Black, percent female aged 18 to 44, and percent with a bachelor's degree or higher. Each county that experiences a maternity ward closure is matched to the county with continuous maternity services with the closest propensity score.<sup>6</sup> Control counties are then assigned the same "closure" date as their corresponding matched treatment county. I can then use the observably similar control county to estimate the counterfactual outcome paths for the treated county had the closure not occurred.

### 3.2 Baseline Specification

To estimate the impact of closure on birth outcomes, I compare changes in the outcomes of interest for treated and control counties around the time of a treated county's closure. I estimate a fully dynamic matched difference-in-differences regression of the form:

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<sup>6</sup>Median household transfers is not available for independent cities in Virginia. Treated counties in Virginia are matched to potential control counties in Virginia based on all other characteristics. The results are robust to alternative matching specifications (e.g., matching on fewer variables, matching on binned categories of variables, and unrestricted matching within the state). I also ensure each potential control is not associated with more than one closure county. Appendix Table A2 assesses the balance between treatment and control counties following the matching procedure.

$$Y_{ct} = \sum_{\tau \neq -1} [\theta_\tau \alpha_\tau + \beta_\tau (Treat_c \times \alpha_\tau)] + \gamma_c + \gamma_t + \varepsilon_{ct}, \quad (1)$$

where  $Y_{ct}$  is the average outcome variable for births occurring to women residing in county  $c$  and time  $t$ , and  $\alpha_\tau$  is the year relative to (the treatment county's) loss of services.  $Treat_c$  is an indicator equal to 1 for counties that experience a loss of hospital-based maternity services,  $\gamma_c$  are county fixed effects,  $\gamma_t$  are calendar time fixed effects, and  $\varepsilon_{ct}$  is an error term. I weight all regressions by the number of births to residents of a county.<sup>7</sup> Standard errors are clustered at the county level.

The coefficients of interest are  $\beta_\tau$ , which represent the treat-control differences in outcome  $Y$  at event time  $\tau$ . I omit  $\tau = -1$ , so each  $\beta_\tau$  represents the treat-control difference at event time  $\tau$ , relative to the same difference at event time  $-1$ . I focus on the  $\beta_\tau$  coefficients from event time  $-6$  to  $6$ , where the treatment and control counties are fully balanced. Effects from event time  $\tau < -6$  and  $\tau > 6$  are accumulated and the coefficients are not reported.

When presenting the results, I typically plot all  $\beta_\tau$  coefficients to observe both pre-trends and the evolution of treatment effects through time. In addition, I summarize the treatment effects by reporting the post-period average of the  $\beta_\tau$  coefficients (i.e.,  $\bar{\beta}_\tau = \frac{1}{7} \sum_{\tau=0}^6 \beta_\tau$ ), which represents the average treatment effect in the post period. I also report an early treatment effect ( $\beta_0$ ) and a late treatment effect ( $\beta_5$ ).

### 3.3 Identification

The identifying assumptions underlying my estimation strategy are as follows: First, both closure and non-closure counties had similar time trends before the treated county's loss of service. Second, in the absence of the loss of service, closure counties would have continued to follow the same trends as those in the non-closure counties.

Under these assumptions, I interpret the  $\beta_\tau$  coefficient as the causal effect of losing

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<sup>7</sup>Unweighted regressions are quantitatively similar and are available in the Appendix.

maternity services on outcome Y. Importantly, identification of this causal effect comes from differences between the closure and non-closure counties. Thus even though the closures themselves are occurring at different calendar times, the effects are estimated as differences between treated and control counties rather than solely leveraging variation in timing.

One concern with the identifying assumptions underlying this empirical strategy is that areas that experience a loss of hospital-based maternity services are different from areas that do not. For example, a county that loses access to maternity services may be on a declining economic path, and this may create a fundamental difference in the type and health of the women residing in that county. Matching on observables helps address this concern by ensuring that treatment and control areas have similar demographic and economic characteristics prior to the closure. In addition, I plot the coefficients from estimates of Equation (1) to assess the presence of pre-trends. To assess potential changes in composition, I estimate Equation (1) using the log of the number of births occurring to residents of a closure county (i.e., fertility) and various demographic characteristics. The results, presented in Appendix Figure A1, do not suggest any changes in fertility or composition.

A related concern is that the control group is selected from the set of counties that always provide maternity services. In particular, areas that continually provide maternity services may be on a different trajectory because they start out larger and more economically connected relative to counties that close their maternity services. I address this concern by checking robustness to the choice of control group using two alternative control groups. In the first, I select control counties from the set of counties that never provided maternity care from 1996 to 2018, seen in Appendix Figures A2 to A4. In the second, I split each state into “early closures” and “late closures,” where the late closures close at least 4 years after the early closures, seen in Appendix Figures A5 to A7. I prefer the control group chosen in the main specification since it maximizes the sample of closure counties and avoids the possibility of a control county being treated before my sample period. Nevertheless, my results are robust to both alternative control groups.

Another threat to the identifying assumption would be the presence of a shock that impacts closure areas, and not control areas, occurring at the same time as the closure. Since most major health policy decisions occur at the state level (rather than a county or zip code level), I mitigate this concern by restricting matches to be nonadjacent counties within the same state. The differences in calendar time of closures as well as the within state matching make it unlikely that the effects are driven by the treated areas experiencing a concurrent shock unrelated to the hospital closure.

## 4 Main Results

### 4.1 Birthing Location

I first consider the impact of the closure on the birthing location. Since the county no longer offers maternity services, nearly all women living in the county should give birth in a county other than their county of residence. There could still be a small number of births occurring within the county if women give birth out-of-hospital or in a hospital that no longer provides maternity services (i.e., deliver in the emergency room). Figure 4 plots the treat-control differences from estimating Equation (1) with the share of births occurring out of county (Panel (a)), share of births occurring out of hospital (Panel (b)), and the share of births occurring in a hospital with an operating maternity ward (Panel (c)).

Following the closure, there is a significant increase in the number of births occurring outside the closure county, as expected. Even before closure, more than three-fourths of women were bypassing their local hospital and giving birth outside of their county of residence. This suggests that the perceived benefit (i.e., higher quality doctors or hospitals) of the out-of-county hospital outweighed the cost of increased travel distance for a majority of women prior to closure. Nonetheless, the share of births occurring out-of-county rises significantly and indicates that after closure nearly 100 percent of births occur out-of-county for women residing in a treatment county.

Following closure, there is a modest increase in out-of-hospital birth and decrease in births occurring in a hospital with a maternity ward. With 99 percent of births in closure counties occurring in hospitals with maternity care, the magnitude of this drop is economically small. Panels (a) through (c) highlight that following closure, nearly all women who reside in a closure county give birth out-of-county, with only small decreases in the share giving birth in a location with maternity care. The results for this subsection, and the two that follow, are summarized in Table 2.

## 4.2 Infant Health

When a maternity ward closes, women have to travel farther distances for delivery. The increase in travel distance in rural areas is likely to be large, as discussed in Section 2. The increase in travel distance could negatively impact infant health if there are reductions in prenatal care or increases in out-of-hospital births. Pregnancies with limited prenatal care and out-of-hospital births could lead to complications and negative impacts on infant health (Moore et al. (1986), Twizer et al. (2001), Vintzileos et al. (2002), and Grünebaum et al. (2020)). In this section, I investigate if the closures have any impact on various measures of infant health.

There are no clear trends that would suggest a negative impact on infant health. Figure 5 plots the treat-control differences from estimating Equation (1) using share of births that are low birth weight (less than 2500 grams), share of births with an Apgar score below 7, share of births preterm (less than 37 weeks gestation), and the infant mortality rate as the dependent variables. Additional outcomes, including as log of birthweight and share of births full-term, are available in Appendix Figure A11. I can rule out relatively small deleterious effects on low birth weight, Apgar scores, and preterm birth. I can reject increases in low birth weight of more than 1.3 percent, increases in the share of births with a low Apgar score of more than 8.3 percent, and increases in preterm birth of more than 0.5 percent. Due to the small baseline infant mortality rate, I cannot rule out even relatively large increases in

infant mortality. However, the fairly precise null effect on other outcomes provides reassuring evidence that the reduction in Cesarean births did not harm infants.

### 4.3 Outcomes of Pregnancy and Birth

Maternity ward closures could indicate potential threats to maternal health if they reduce prenatal care, even in the absence of negative effects to infants. In addition, maternity ward closures could impact medical interventions during delivery, such as induction or Cesarean birth. This section explores the impact of closures on these channels.

The increased travel distance can impact maternal outcomes through decreased utilization of prenatal care. When a county loses its maternity ward, the women in the county may also lose their access to prenatal care if the obstetricians relocate to other areas or if prenatal care was provided in the hospital. Panels (a) and (b) of Figure 6 plot the treat-control differences in the share of pregnancies with no prenatal care and share of pregnancies with low ( $\leq 10$ ) prenatal visits. There is no significant increase in the share of births with no prenatal visits for women residing in closure counties relative to the matched control counties. There is an increase in the share of pregnancies with low prenatal visits. The average point estimate of 0.040 suggests a 10 percent increase in the share of pregnancies with low prenatal visits. Taken together, Panels (a) and (b) suggests that women are not foregoing prenatal care entirely, but some women do receive fewer prenatal visits following closures.

To avoid potentially lengthy drives to the closest hospital with a maternity ward during active labor, women may elect to have an induction. Elective inductions can usually be scheduled at 39 weeks gestation and are associated with a decreased risk of Cesarean birth in post-term deliveries past 41 weeks of gestation. However, earlier inductions may be associated with an increased risk of Cesarean birth (Caughey et al. (2009)). Panel (c) of Figure 6 provides evidence *against* the notion that women choose to have an elective induction following closure. The figure shows that the rate of inductions does not increase relative following closure.

Panel (d) of Figure 6 plots the treat-control differences in the share of births delivered via Cesarean. The post-period treat-control differences are significantly negative. The share of births delivered via Cesarean decreases for women residing in closure counties by approximately 2 percentage points following closure, relative to the same difference for women residing in matched control counties, which is roughly a 6 percent decrease. Taken together, Panels (c) and (d) suggest induction does not increase and the Cesarean rate decreases. I present unweighted results for this and the prior 2 sections in Appendix Figures A12 to A14, and the results are similar. I explore the reductions in Cesareans, and whether it has a positive or negative impact on women, in Section 5.

## 5 Analysis of Reduction in Cesarean Birth

The results from the main analysis suggest that the closure of a rural maternity ward reduces Cesarean deliveries for women residing in closure counties. Since Cesarean delivery carries a greater risk of severe maternal morbidity, the reduction in Cesarean deliveries could be a benefit of closure if it reduces unnecessary procedures. However, the reduction could be a cost of closure if it reduces Cesareans among women who cannot safely deliver vaginally. To investigate this, I study whether the decrease in the rate of Cesarean births occurs among high- or low-risk women. In addition, I explore the role of provider delivery practices in explaining the reduction in Cesarean births.

### 5.1 Results by Maternal Risk Factors

A Cesarean birth is a major surgery. As with other surgeries, Cesareans come with serious risks, such as infection, hemorrhage, and blood clots. In addition, Cesareans also have the potential to create long-term effects, such as damage to reproductive organs. A Cesarean birth in one pregnancy often leads to future Cesarean births, with more than three-quarters of women with a history of Cesarean birth having a repeat Cesarean with future births

([Osterman et al. \(2020\)](#)). However, a Cesarean birth can also be a life-saving surgery and allow an infant to be born safely when a vaginal birth is otherwise unsafe. To minimize the potential risks and maximize the benefits, Cesareans should be performed only on women and infants who would face worse outcomes if delivery were to occur vaginally.

Since I cannot determine how women would have fared in their counterfactual delivery, I instead investigate if the reduction in Cesarean births occurs among both high- and low-risk women. If women who are observably high-risk experience a reduction in Cesarean deliveries following the maternity ward closure, the closure is impacting women for whom the costs of not receiving Cesareans are very high. On the other hand, if reductions are concentrated among women for whom Cesareans are less appropriate, this could suggest that unnecessary Cesareans have been reduced. In particular, ACOG highlights the rapid increase in Cesarean deliveries since the 1990s as evidence that Cesarean births may be overused among low-risk women ([ACOG \(2014\)](#)).

To assess risk levels, I follow [Currie and MacLeod \(2017\)](#) and estimate the following logistic model:

$$\text{Prob}(C_i = 1) = F(\beta X_i), \quad (2)$$

where  $C_i$  is an indicator if the birth was delivered via Cesarean and  $X_i$  are purely medical observable risk factors available consistently in the birth certificate data. The inputs used in the logit regression are mother's age, birth order, previous Cesarean, plurality of birth, breech presentation, blood pressure disorders (eclampsia, chronic hypertension, and gestational hypertension), and diabetes. I estimate the model on all births in the closure counties and the corresponding matched control counties.

The distribution of the estimated propensity scores, which can be viewed as the “appropriateness for a Cesarean,” is displayed in Figure 7. The figure shows that most women who do not deliver via Cesarean have a propensity score below 0.30. For women who do deliver via Cesarean, there is a lot of mass both above 0.80 and below 0.30, highlighting that a considerable number of women with minimal observable risk factors nevertheless receive a

Cesarean.

I investigate how the reduction in Cesareans changes by the appropriateness for a Cesarean in Figure 8. Based on the distribution of Figure 7, I split women above and below the 0.30 cutoff based on their propensity scores derived from estimating Equation (2). I then re-estimate Equation (1) separately for both high- and low-risk women. Figure 8 plots the treat-control difference in the share of births delivered via Cesarean for both groups. The coefficients for the low-risk women (the women least appropriate for Cesarean birth) are displayed in Panel (a), and for the high-risk women in Panel (b). The results from these figures are summarized in Table 3.

The decrease in the share of births delivered via Cesarean is only visible for women with low levels of risk. These women are the least appropriate candidates for a Cesarean, with an estimated propensity score of less than 0.30. The average post-period coefficient of -0.010, as seen in Table 3, indicates that closure is associated with a reduction in the rate of Cesarean birth of roughly 1 percentage point. With a Cesarean rate of 16.4 percent for low-risk women, this represents a 6 percent decrease. High-risk women, on the other hand, do not experience a reduction in Cesarean births, as seen in Panel (d) of Figure 8.

Since the reduction in Cesarean births is driven by low-risk women, the decrease in Cesarean births can be viewed as a benefit of closure. It would be worrying if the decrease was concentrated among the riskiest women, but this is reassuringly not the case. While I am unable to study outcomes such as maternal morbidity or mortality due to data limitations, I view the reduction in Cesarean births as a benefit since the reduction is concentrated among low-risk women and there are no adverse outcomes for infants.

## 5.2 Impact of Provider Practice

A potential explanation for the reduction in Cesarean deliveries could be that providers in the hospitals that close have a higher propensity to perform Cesareans. There is considerable variation in the use of Cesarean birth across hospitals, ranging from 19 percent to 48 percent

(Card et al. (2019)). If women are shifted from hospitals with a high Cesarean rate to hospitals with a low Cesarean rate, there could be a reduction in Cesarean deliveries due to exposure to different provider practices.

I begin by identifying what county women who experience a closure deliver in following closure. Since women may decide to give birth in any county following closure, there could be several potential “receiving” counties. To have one receiving county per closure county, I create a “weighted receiving county,” where the weights are determined by the share of closure county births occurring in each receiving county<sup>8</sup>

To investigate if closure counties perform relatively more Cesareans, I plot the raw rates of Cesarean birth in closure and receiving counties leading up to the closure of the maternity ward in Figure 9. Panel (a) plots the average Cesarean rate in a closure county and in a receiving county leading up to closure. Panel (b) plots the average Cesarean rate among low-risk women (i.e., women with a propensity score of less than 0.30) in a closure county and in a receiving county leading up to closure, while Panel (c) plots the Cesarean rates among high-risk women. All panels are weighted by the relevant number of births occurring in a county. Closure counties have a higher rate of Cesarean births, though not significantly more. In addition, the gap between closure and receiving counties widens over the pre-closure years, stemming from an increase in the Cesarean rate among low-risk women.

To investigate the role of provider practice, I split my sample into three groups: (1) receiving county has a higher rate of Cesarean birth, (2) receiving county has a lower rate of Cesarean birth, and (3) receiving county has an approximately equal rate of Cesarean birth. To create these three groups, I first calculate the difference in the pre-closure rate of Cesarean births occurring in the closure and receiving counties. I then split this difference into terciles. The group where the receiving county has a higher rate has an average differ-

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<sup>8</sup>In particular, the set of potential receiving counties are the counties that have at least one birth from the closure county in each of the 5 years following closure. The weights are determined by dividing the number of births to closure women in a specific receiving county by the total number of births to receiving women in all potential receiving counties in the year following closure.

ence of 9.6 percentage points (range: 3.2 to 24.0 percentage points). The group where the receiving county has a lower rate has an average difference of  $-9.9$  percentage points (range:  $-2.9$  to  $-57.0$  percentage points). The group where the closure and receiving county have approximately equal rates has an average difference of 0.0 percentage points (range:  $-2.9$  to 3.0 percentage points). I re-estimate Equation (1) separately on each of the three groups.

I find the strongest reductions in Cesarean births when women shift from areas with a high rate of Cesarean births into areas with a low rate of Cesarean births. The point estimates for each tercile are shown in Figure 10 and summarized in Table 4. In Panel (a), where women are shifted from areas with high Cesarean rates to areas with low Cesarean rates, the average post-period coefficient of 0.022 suggests maternity ward closure is associated with approximately a 2.2 percentage point (6.9 percent) decrease in the rate of Cesarean birth following closure, relative to the matched control counties. I do not find as strong of a decrease in the other groups. The results from this section suggest that provider practice is important. Cesarean rates decrease the most for women residing in counties that have a higher rate of Cesarean birth before closure relative to the receiving county.

## 6 Additional Results

### 6.1 Results by Access to Care

My results show that rural maternity ward closures do not lead to negative effects on health outcomes. To reconcile my null results with the concerns presented in the media, I perform a heterogeneity analysis looking at differential access to alternative maternity care. There may be negative effects of hospital closures in more remote areas where travel time to the nearest alternative is high.

To study if outcomes vary between more and less remote areas, I first determine what options women have following the maternity ward closure. I use two definitions of available alternatives since I am unable to observe a woman's exact residence in the birth certificate

data. In the first measure, I use the AHA Annual Survey to determine how many hospitals provide maternity care in the counties surrounding the county that experiences a closure. In the second measure, I estimate the average distance a woman in a closure county would need to travel to the next closest hospital with a maternity ward. To do this, I use the center of population calculated by the U.S. Census Bureau based on the 2000 Census to get the population-weighted centroid of a closure county. I then calculate the travel distance to the nearest maternity ward using the hospital location information provided in the AHA Annual Survey.

I split the sample at the median level of access and estimate Equation (1) separately on counties above and below median. Results for selected outcomes are displayed in Figure 11 and summarized in Tables 5 and 6. The remaining outcomes are available in Appendix Figures A15 to A17. The definition of access in panels (a), (c), and (e) is the number of hospitals with a maternity ward in adjacent counties, and in panels (b), (d), and (f), I define it as the distance to the nearest hospital with a maternity ward.

Before closure, a majority of women in both groups gave birth out-of-county. In more remote areas if there are not as many good options nearby, a woman may be more inclined to stick with her local hospital. On the other hand, a closure county that has more access to alternatives would likely have higher levels of out-of-county births before closure. If a woman does not need to travel very far or has many outside options, it will be easier for her to bypass her local hospital. If more women give birth in-county before closure, a maternity ward closure could have a larger impact compared to areas where less women give birth in-county. The dependent variable in panels (a) and (b) of Figure 11 is the share of births occurring out-of-county. In the period before closure, around 75 percent of women in low access areas gave birth out of county compared to 81 percent of women in high access areas. Interestingly, even if there are not as many nearby options, a majority of women are still bypassing the local hospital.

When access to alternatives is more extremely limited, women may be more likely to give

birth outside of a maternity ward (e.g., a home birth or in a hospital without a maternity ward). Panels (c) and (d) plot the treat-control difference for the share of births occurring in a hospital with a maternity ward. The plot indicates the decrease in the share of births occurring in hospitals with a maternity ward is roughly similar, regardless of access to alternatives.

Since rates of Cesarean births significantly decreased in the baseline results, I plot the treat-control differences for Cesarean births by access levels in panels (e) and (f). Areas with both above and below median levels of access see similar reductions in the rate of Cesarean births in the first four years following closure.

## 6.2 Effects of Closure on Receiving Women

Having established the baseline impacts on women residing in the closure counties, I now turn to another potentially impacted group: women residing in the receiving counties. Women residing in the receiving counties could be impacted if the closure of a nearby hospital results in overcrowding, which could negatively impact the quality of care. However, as discussed in Section 2, this channel is likely to be small for rural closures since the number of births in a hospital before closure is relatively small. The results from estimating Equation (1) on the sample of receiving counties and their controls are summarized in Table 7. Detailed regression plots are available in Appendix Figures A18 to A20.

Since the number of women giving birth in the closure county prior to closure is small relative to the receiving counties, the closure is unlikely to generate overcrowding or any other negative spillover effects. Out-of-county and out-of-hospital births could increase, and utilization of prenatal care could decrease, if receiving women were faced with more strained hospitals. However, the point estimates are small and insignificant, suggesting no effect. In addition, I find no impacts on the remaining outcomes for pregnancy or infant health. The results of this section show that the rural closures can be easily absorbed into the surrounding areas with little impact.

### 6.3 Results by Subgroup

Maternal and infant health in the United States lags other peer countries. Within the United States, disparities in maternal and infant health exist along racial, ethnic, and socioeconomic lines. For example, the infant mortality rate for Black infants in 2018 was 10.8 per 1,000 live births, compared to 4.6 for non-Hispanic white infants ([Ely and Driscoll \(2020\)](#)). Maternity ward closures also disproportionately occur in counties with higher proportions of non-Hispanic Black women and lower median household incomes ([Hung et al. \(2017\)](#)).

In this section, I investigate if the loss of maternity services exacerbated any existing maternal and infant health disparities by looking at results across various subgroups. I look at heterogeneity by race and ethnicity (non-Hispanic Black and Hispanic), education (high school or below and more than college), and age (under 20 years old and more than 35 years old). I estimate Equation (1) on the sample of births in a county of the specified demographic characteristic, ensuring the analysis sample is fully balanced by dropping treat-control county pairs that lose balance in the subsample. The post-period average treat-control differences are summarized in Table 8, and the full regression plots are available in Appendix Figures A23 to A30.

Looking across the different samples, no demographic subgroup is particularly impacted by the maternity ward closures. The results for most demographic groups are consistent with the results found on average. The reduction in Cesarean births is driven by young women and black women. Advanced maternal age (older than 35 years) is considered riskier than births in the 20 to 34 age range, with a higher prevalence of obstetric complications, maternal morbidities, and adverse infant health outcomes ([Lisonkova et al. \(2017\)](#)). Women over the age of 35 do not see any changes in out-of-hospital birth or birth in a hospital with a maternity ward, suggesting that this group of “riskier” women are still delivering in a hospital with a maternity ward and an obstetrician.

## 7 Conclusion

This paper studies the impact of losing access to hospital-based maternity care on health outcomes for women and infants in rural areas. Advocates argue that increased travel distances harm women and infants by increasing out-of-hospital birth, reducing prenatal care, and increasing elective inductions, resulting in the “cascade of interventions” that ultimately ends in a Cesarean birth. Alternatively, maternity ward closures could benefit women if closures expose women to higher-quality providers and better-resourced hospitals.

To estimate the causal effect of rural maternity ward closures on birth outcomes, I employ a matched difference-in-differences design and study closures in rural areas. I do not find support for the concerns raised above and instead find that closures appear to create a net benefit. I do not find that closures are associated with adverse health outcomes for the infants. In fact, I find relatively precise null effects on low birth weight, Apgar scores, and preterm births. In addition, my results suggest the rate of Cesarean births decreases. Local provider practice plays an important role in the decrease in Cesarean births. Women who shift from areas that perform relatively more Cesarean births see the largest reductions. In addition, the decrease in Cesarean births is concentrated among low-risk women, suggesting the closures reduced of unnecessary Cesarean procedures.

These results suggest the concern surrounding “maternity care deserts” may be missing an important component. It is important to have access to high-quality care for rural women, but the maternity ward closures that have naturally occurred in these areas do not have significantly negative impacts on women or children. Most women are bypassing these hospitals and are opting for an out-of-county birth before closure, suggesting that women already perceive the benefits of a different hospital to outweigh the costs of increased travel. The results suggest the hospitals that are closing in rural areas are providing worse care and when a closure forces women to give birth elsewhere, health outcomes improve.

A limitation of this study is the inability to study outcomes not present on the birth record. Closures could lead to adverse outcomes in the form of challenges with transportation

or childcare, lack of communication between providers in the residence county and delivery county, and maternal stress due to the closure. The results of this paper suggest the benefits of being shifted to a higher-quality provider outweigh the costs of increased distance as measured by the outcomes on the medical record. However, future research and policy programs should address the potential adverse effects on these alternative outcomes.

The findings of this paper offer several takeaways for policy considerations. Closures are not always negative, and it may not be a worthwhile policy effort to ensure that all hospitals continue to provide maternity services. The rural closures that have naturally occurred have not been detrimental to maternal or infant health. Providing funding to keep rural maternity wards open may not generate returns large enough to justify the cost, and there are likely more effective ways to improve maternal and infant health.

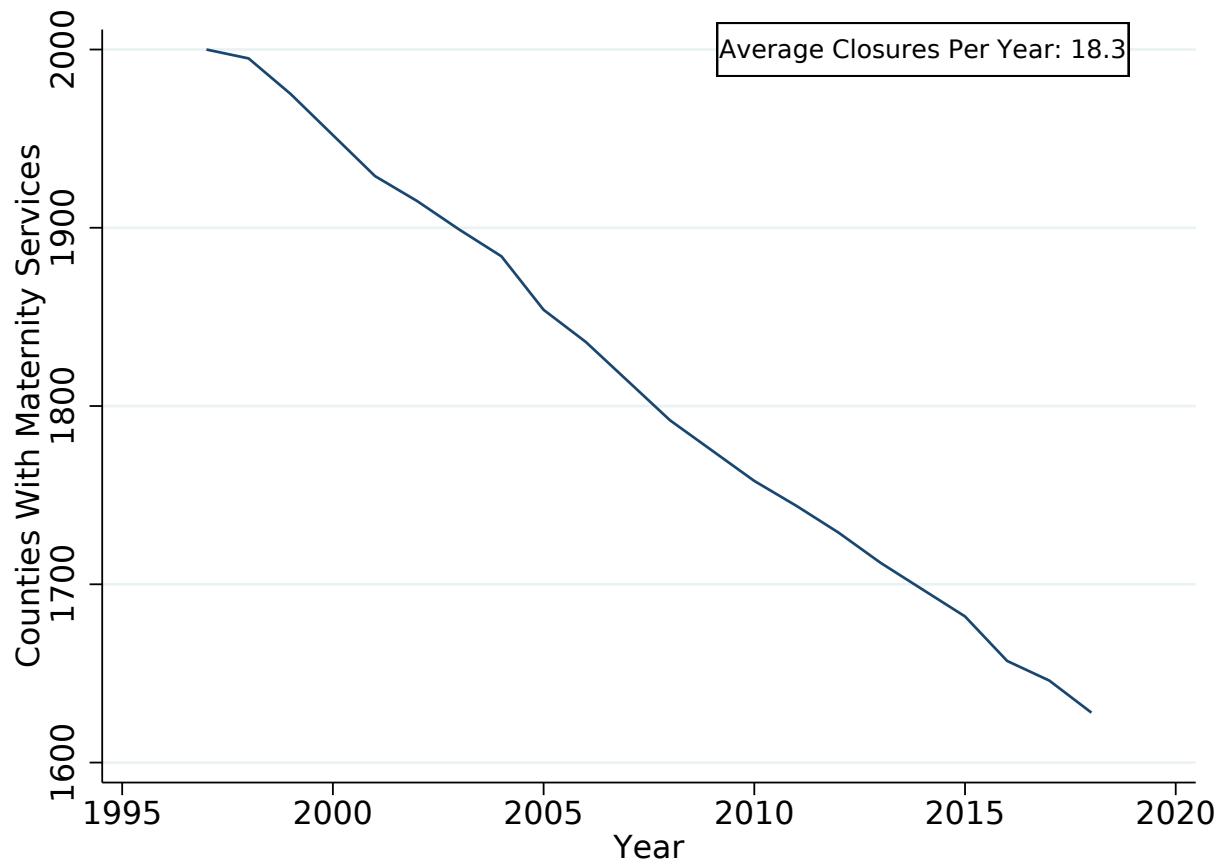
## References

- ACOG (2014). Safe Prevention of the Primary Cesarean Delivery. Obstetric Care Consensus No. 1. . *American Journal of Obstetrics and Gynecology*.
- Aizer, A., J. Currie, and E. Moretti (2007). Does Managed Care Hurt Health? Evidence from Medicaid Mothers. *The Review of Economics and Statistics* 89(3), 385–399.
- Almond, D., J. Currie, and M. Herrmann (2012). From Infant to Mother: Early Disease Environment and Future Maternal Health. *Labour Economics* 19(4), 475–483.
- Almond, D., J. Currie, and E. Simeonova (2011). Public vs. Private Provision of Charity Care? Evidence from the Expiration of Hill–Burton Requirements in Florida. *Journal of Health Economics* 30(1), 189–199.
- Avdic, D., P. Lundborg, and J. Vikström (2018). Mergers and Birth Outcomes: Evidence From Maternity Ward Closures.
- Bridgewater, B., A. D. Grayson, J. Au, R. Hassan, W. C. Dihmis, C. Munsch, and P. Waterworth (2004). Improving Mortality of Coronary Surgery Over First Four Years of Independent Practice: Retrospective Examination of Prospectively Collected Data From 15 Surgeons. *The BMJ* 329(7463), 421.
- Callaway, B. and P. H. Sant'Anna (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics* 225(2), 200–230.
- Card, D., A. Fenizia, and D. Silver (2019). The Health Impacts of Hospital Delivery Practices. Technical report, National Bureau of Economic Research.
- Caughey, A. B., V. Sundaram, A. J. Kaimal, Y. W. Cheng, A. Gienger, S. E. Little, J. F. Lee, L. Wong, B. L. Shaffer, S. H. Tran, et al. (2009). Maternal and Neonatal Outcomes of Elective Induction of Labor. *Evidence Report/Technology Assessment* (176), 1.
- Chen, A., E. Oster, and H. Williams (2016). Why Is Infant Mortality Higher In The United States Than In Europe? *American Economic Journal: Economic Policy* 8(2), 89–124.
- Contreras, J. M., B. Kim, and I. M. Tristao (2011). Does Doctors' Experience Matter in LASIK Surgeries? *Health Economics* 20(6), 699–722.
- Costa-Ramón, A., M. Kortelainen, A. Rodríguez-González, and L. Sääksvuori (2020). The Long-Run Effects of Cesarean Sections. *Journal of Human Resources*, 0719–10334R1.
- Costa-Ramón, A. M., A. Rodríguez-González, M. Serra-Burriel, and C. Campillo-Artero (2018). It's About Time: Cesarean Sections and Neonatal Health. *Journal of Health Economics* 59, 46–59.
- Currie, J. and W. B. MacLeod (2008). First Do No Harm? Tort Reform and Birth Outcomes. *The Quarterly Journal of Economics* 123(2), 795–830.

- Currie, J. and W. B. MacLeod (2017). Diagnosing Expertise: Human Capital, Decision Making, and Performance Among Physicians. *Journal of Labor Economics* 35(1), 1–43.
- Currie, J. and P. B. Reagan (2003). Distance to Hospital and Children's Use of Preventive Care: Is Being Closer Better, and For Whom? *Economic Inquiry* 41(3), 378–391.
- Ely, D. M. and A. K. Driscoll (2020). Infant Mortality in the United States, 2018: Data From the Period Linked Birth/Infant Death File. *National Vital Statistics Reports: From the Centers for Disease Control and Prevention, National Center for Health Statistics, National Vital Statistics System* 69(7), 1–18.
- Evans, W. N. and C. L. Garthwaite (2014). Giving Mom a Break: The Impact of Higher EITC Payments on Maternal Health. *American Economic Journal: Economic Policy* 6(2), 258–90.
- Fischer, S. J., H. Royer, and C. D. White (2022). Health care centralization: The health impacts of obstetric unit closures in the us. Technical report, National Bureau of Economic Research.
- Grünebaum, A., L. B. McCullough, B. Orosz, and F. A. Chervenak (2020). Neonatal Mortality in the United States is Related to Location of Birth (Hospital Versus Home) Rather Than the Type of Birth Attendant. *American Journal of Obstetrics and Gynecology* 223(2), 254–e1.
- Halm, E. A., C. Lee, and M. R. Chassin (2002). Is Volume Related to Outcome in Health Care? A Systematic Review and Methodologic Critique of the Literature. *Annals of Internal Medicine* 137(6), 511–520.
- Hung, P., M. M. Casey, K. B. Kozhimannil, P. Karaca-Mandic, and I. S. Moscovice (2018). Rural-Urban Differences in Access to Hospital Obstetric and Neonatal Care: How Far is the Closest One? *Journal of Perinatology* 38(6), 645–652.
- Hung, P., C. E. Henning-Smith, M. M. Casey, and K. B. Kozhimannil (2017). Access to Obstetric Services in Rural Counties Still Declining, With 9 Percent Losing Services, 2004–14. *Health Affairs* 36(9), 1663–1671.
- Hussung, A. K. (2018). *How Concerned Should We Be When A Rural Obstetric Unit Closes Its Doors? Evidence From An Event Study.* Ph. D. thesis, Miami University.
- Kozhimannil, K. B., P. Hung, C. Henning-Smith, M. M. Casey, and S. Prasad (2018). Association Between Loss of Hospital-Based Obstetric Services and Birth Outcomes in Rural Counties in the United States. *Jama* 319(12), 1239–1247.
- Kuziemko, I., K. Meckel, and M. Rossin-Slater (2018). Does Managed Care Widen Infant Health Disparities? Evidence From Texas Medicaid. *American Economic Journal: Economic Policy* 10(3), 255–83.
- Lewis, C., I. Paxton, and L. Zephyrin (2019, Aug). The Rural Maternity Care Crisis.

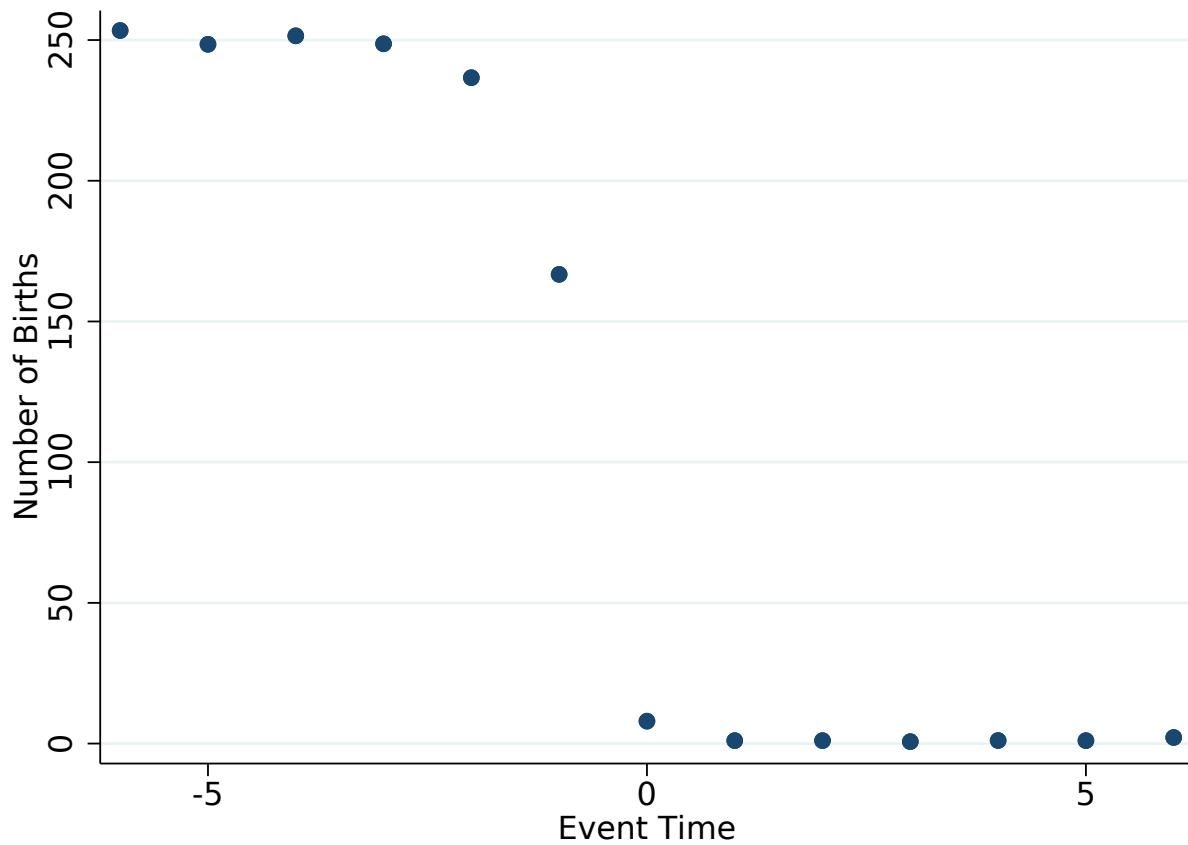
- Lisonkova, S., J. Potts, G. M. Muraca, N. Razaz, Y. Sabr, W.-S. Chan, and M. S. Kramer (2017). Maternal Age and Severe Maternal Morbidity: A Population-Based Retrospective Cohort Study. *PLoS Medicine* 14(5), e1002307.
- Lorch, S. A., S. K. Srinivas, C. Ahlberg, and D. S. Small (2013). The Impact of Obstetric Unit Closures on Maternal and Infant Pregnancy Outcomes. *Health Services Research* 48(2pt1), 455–475.
- Lu, Y. and D. J. Slusky (2016). The Impact of Women’s Health Clinic Closures on Preventive Care. *American Economic Journal: Applied Economics* 8(3), 100–124.
- March of Dimes (2020). *Nowhere To Go: Maternity Care Deserts Across the U.S.*
- Moore, T. R., W. Origel, T. C. Key, and R. Resnik (1986). The Perinatal and Economic Impact of Prenatal Care in a Low-Socioeconomic Population. *American Journal of Obstetrics and Gynecology* 154(1), 29–33.
- National Center for Health Statistics (1996-2018). All-County Birth Cohort Linked Birth/Infant Death Files, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.
- National Center for Health Statistics (2003-2004). All-County Natality Files, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.
- OECD (2019). *Health at a Glance 2019.*
- Osterman, M. et al. (2020). Recent Trends in Vaginal Birth After Cesarean Delivery: United States, 2016–2018.
- Twizer, I., E. Sheiner, M. Hallak, M. Mazor, M. Katz, and I. Shoham-Vardi (2001). Lack of Prenatal Care in a Traditional Society. Is it an Obstetric Hazard? *The Journal of Reproductive Medicine* 46(7), 662–668.
- Vickers, A. J., F. J. Bianco, A. M. Serio, J. A. Eastham, D. Schrag, E. A. Klein, A. M. Reuther, M. W. Kattan, J. E. Pontes, and P. T. Scardino (2007). The Surgical Learning Curve for Prostate Cancer Control After Radical Prostatectomy. *Journal of the National Cancer Institute* 99(15), 1171–1177.
- Vintzileos, A. M., C. V. Ananth, J. C. Smulian, W. E. Scorza, and R. A. Knuppel (2002). The Impact of Prenatal Care in the United States on Preterm Births in the Presence and Absence of Antenatal High-Risk Conditions. *American Journal of Obstetrics and Gynecology* 187(5), 1254–1257.

Figure 1: Number of Counties with Maternity Services



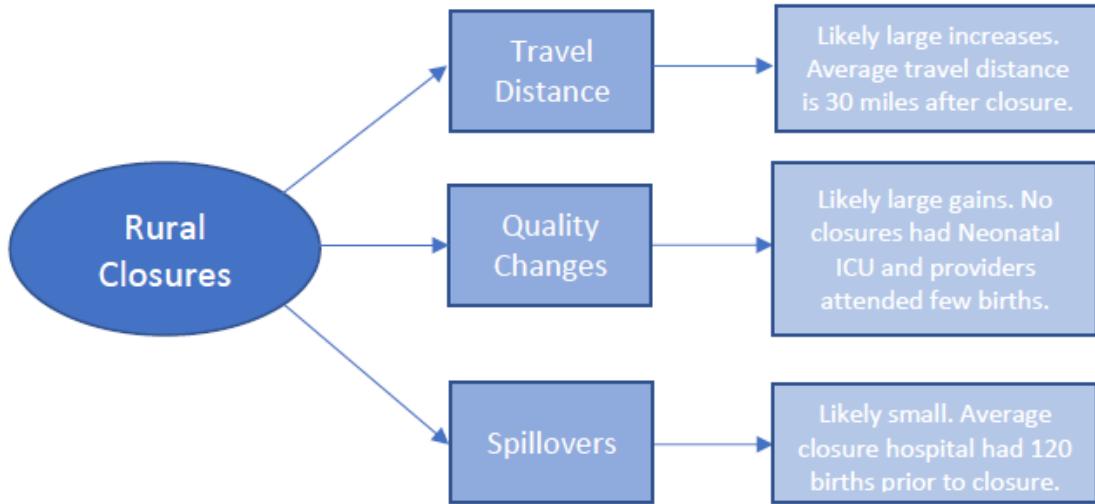
*Note:* This figure displays the number of counties with maternity services from 1997 to 2018. Counties are identified as offering maternity services based on the presence of hospital births in the county in the Vital Statistics data.

Figure 2: Births Occurring in a County Around Closure



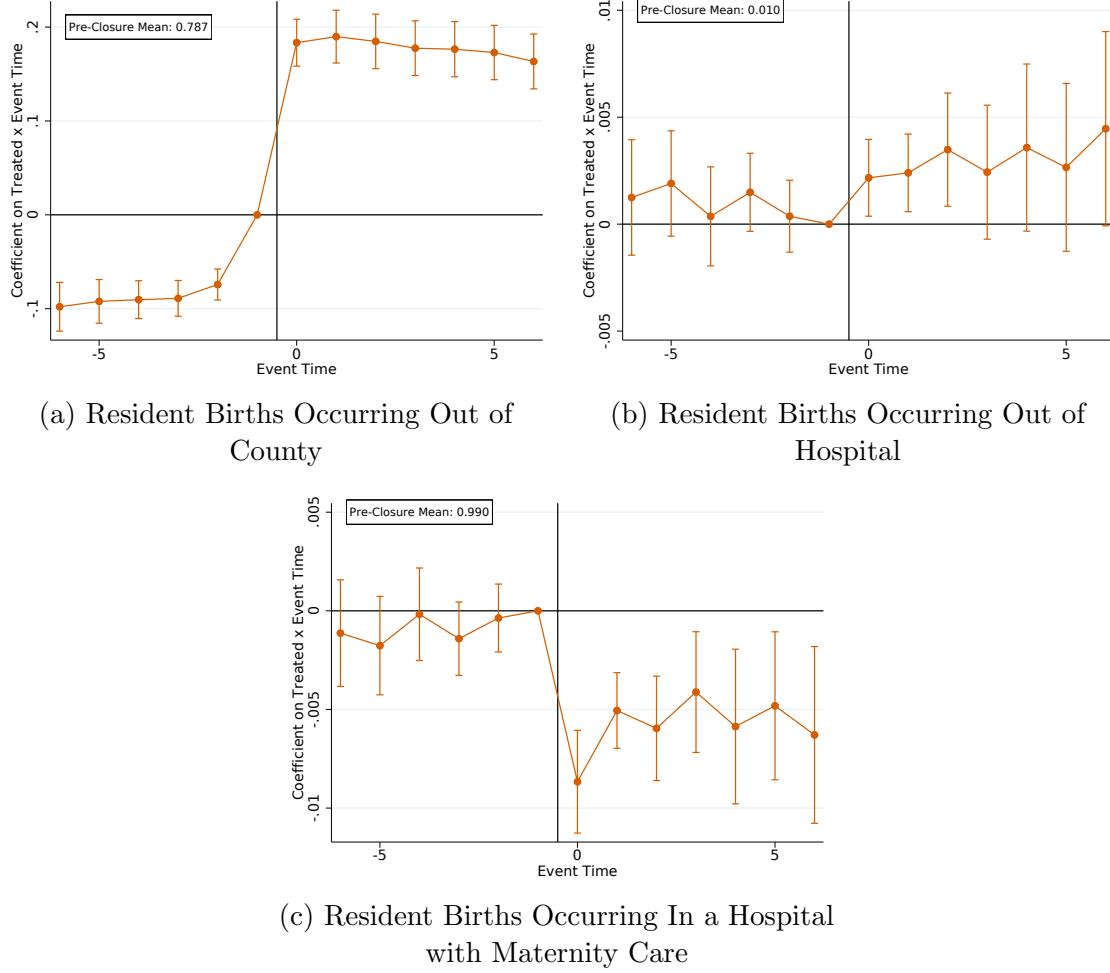
*Note:* This figure plots the average number of hospital births occurring in a county around the time of a county's identified year of closure. The sample consists of counties that experience a loss in maternity care services between 2002 and 2012.

Figure 3: Potential Impacts of Rural and Urban Closures



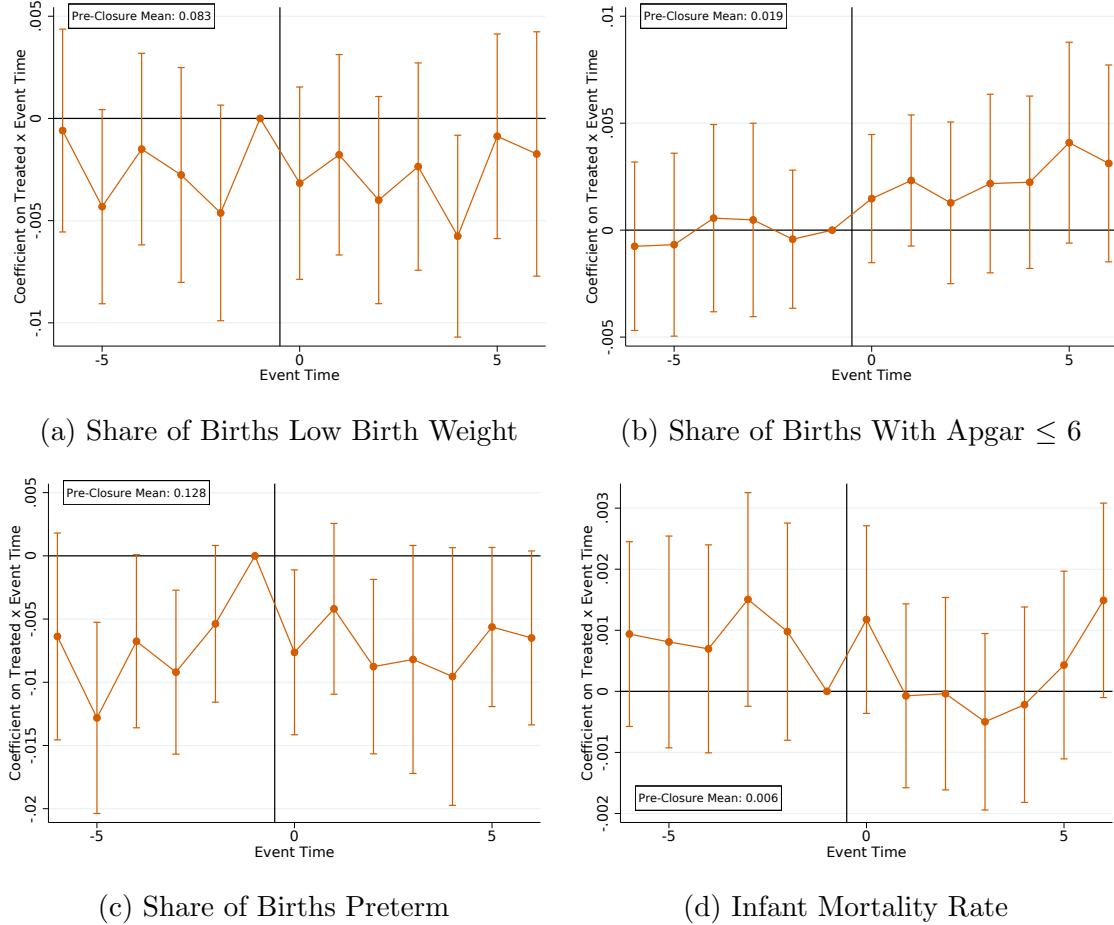
*Note:* This figure summarizes the potential channels through which a maternity ward closure could impact health outcomes in rural areas.

Figure 4: Estimated Impact of Closure on County Births



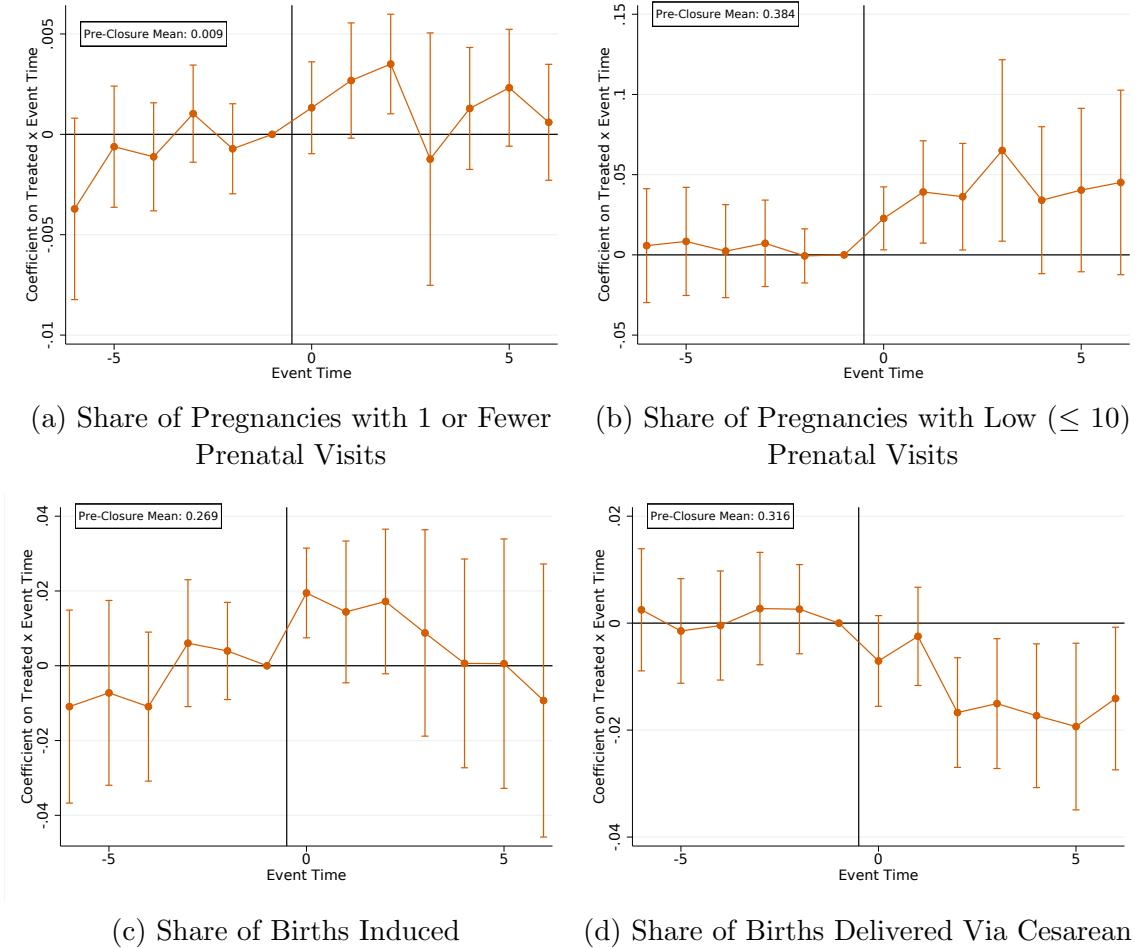
*Note:* In Panels (a) - (c), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating Equation (1). The dependent variable in Panel (a) is the share of births occurring to residents of a county occurring outside of the residence county, in Panel (b) is the share of births occurring outside of a hospital, and in Panel (c) is the share of births occurring in a hospital with an active maternity ward. Observations are at the county-event time level and are clustered at the county level.

Figure 5: Estimated Impact of Closure on Infant Health



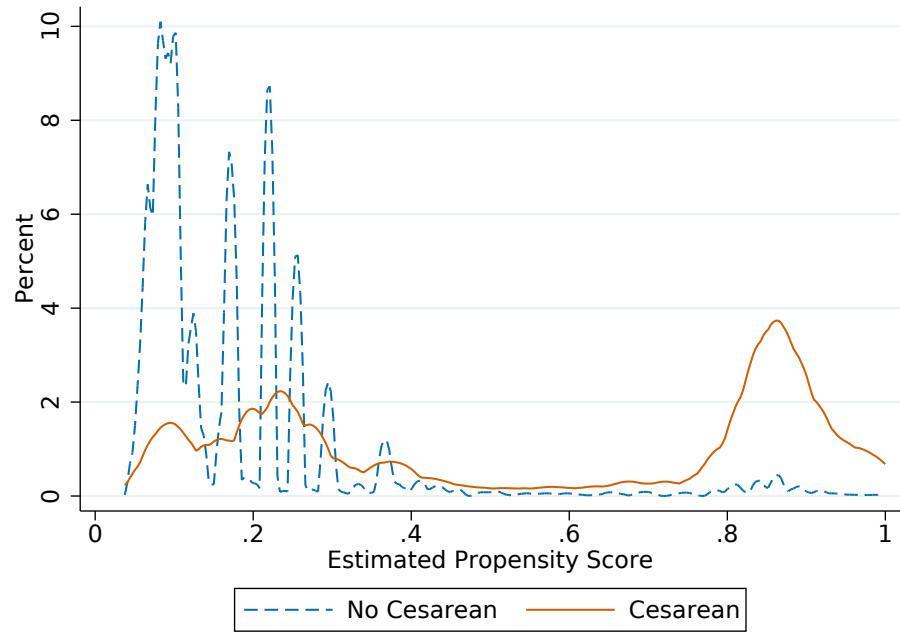
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating Equation (1). The dependent variable in Panel (a) is the share of births low birth weight ( $< 2500$  grams), in Panel (b) is the share of births with an Apgar score less than or equal to 6, in Panel (c) is the share of births preterm ( $< 37$  weeks gestation), and in Panel (d) is the infant mortality rate. Observations are at the county-event time level and are clustered at the county level.

Figure 6: Estimated Impact of Closure on Pregnancy and Birth Outcomes



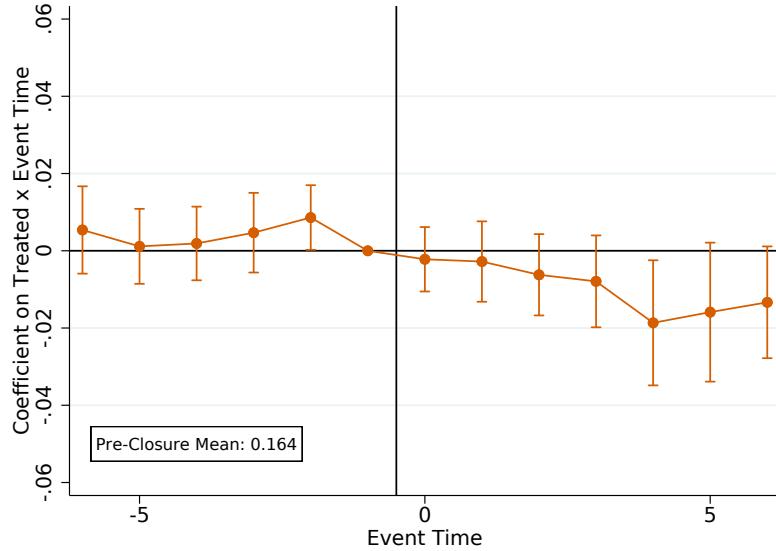
Note: In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating Equation (1). The dependent variable in Panel (a) is the share of births occurring outside of a hospital, in Panel (b) is the share of pregnancies with one or fewer prenatal visits, in Panel (c) is the share of births induced, and in Panel (d) is the share of deliveries that occur via a Cesarean. Observations are at the county-event time level and are clustered at the county level.

Figure 7: Distribution of Estimated Propensity Scores by Delivery Method

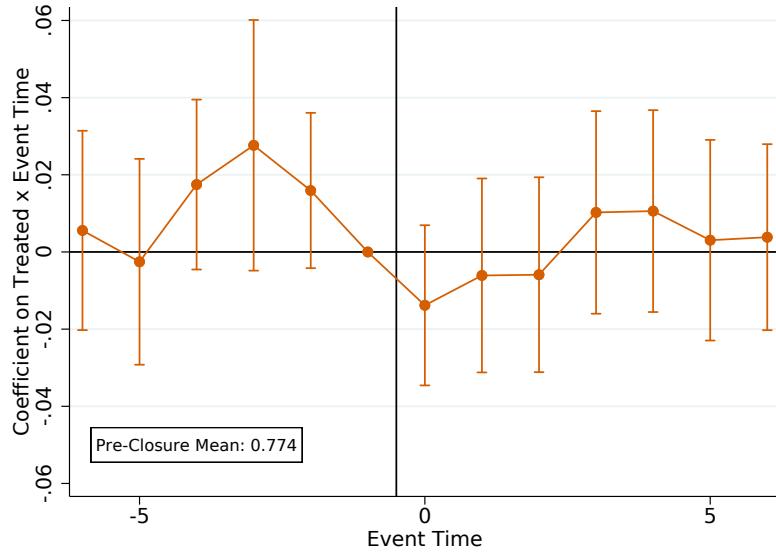


*Note:* This figure plots the kernel density of the estimated propensity scores from estimating Equation (2) for women who did deliver via Cesarean and for women who did not deliver via Cesarean. The sample consists of all women who reside in the closure and control counties.

Figure 8: Estimated Impact of Closure on Share of Births Delivered Via Cesarean by Pregnancy Risk



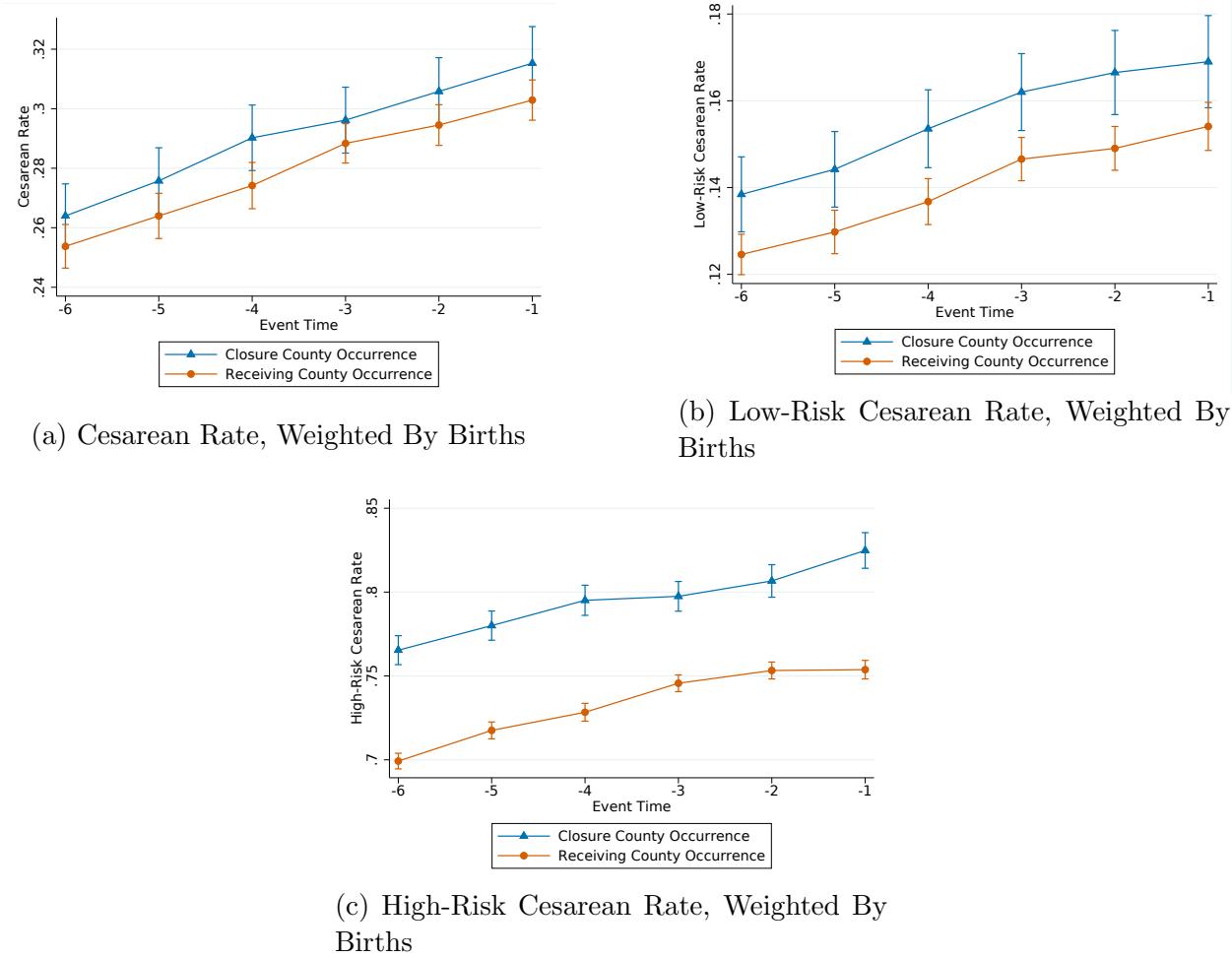
(a) Low-Risk Women



(b) High-Risk Women

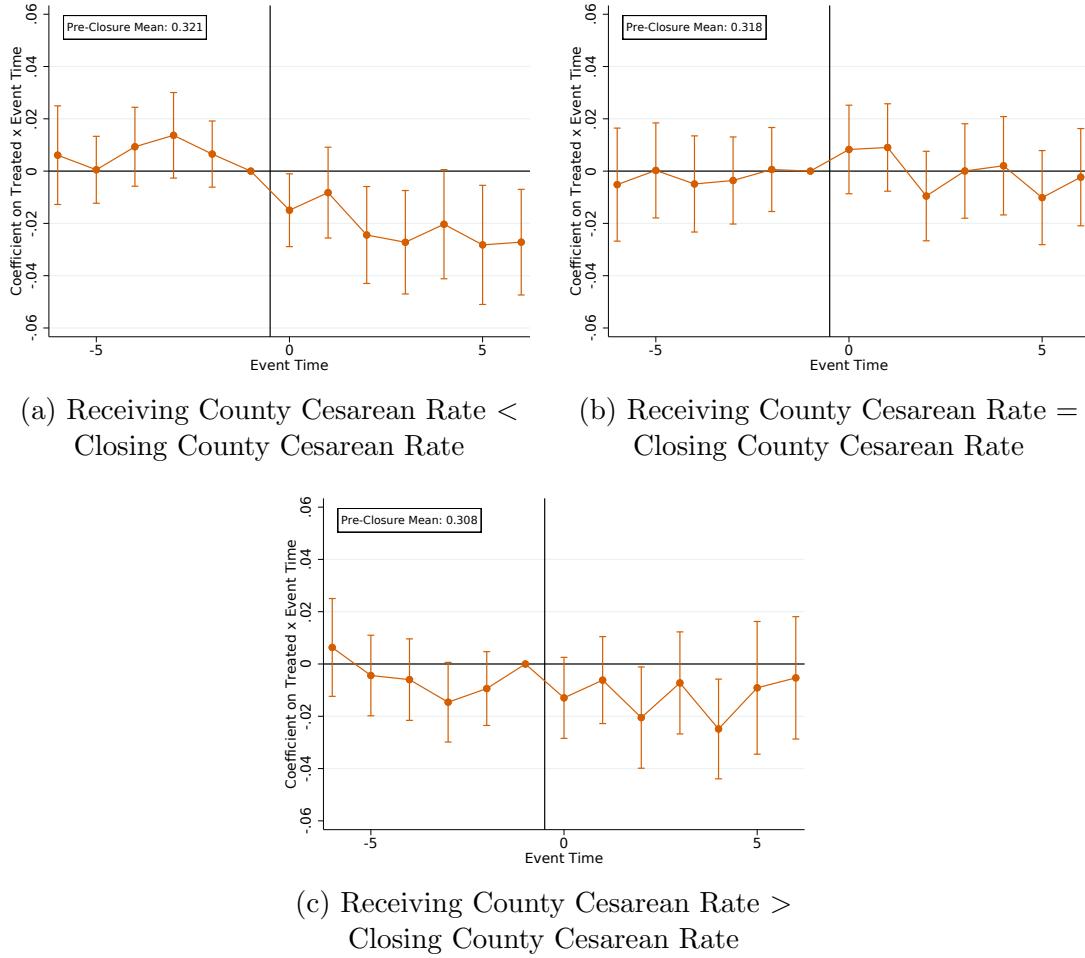
*Note:* In Panels (a) and (b), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating Equation (1). The dependent variable in both panels is the share of births delivered via Cesarean. Panel (a) is estimated on the sample of births in a county that falls below a predicted probability of Cesarean (PPC) of 0.30. Panel (b) is estimated on the sample of births in a county that falls above a PPC of 0.30. Observations are at the county-event time level and are clustered at the county level.

Figure 9: Rate of Cesarean Sections in Closure and Receiving Counties



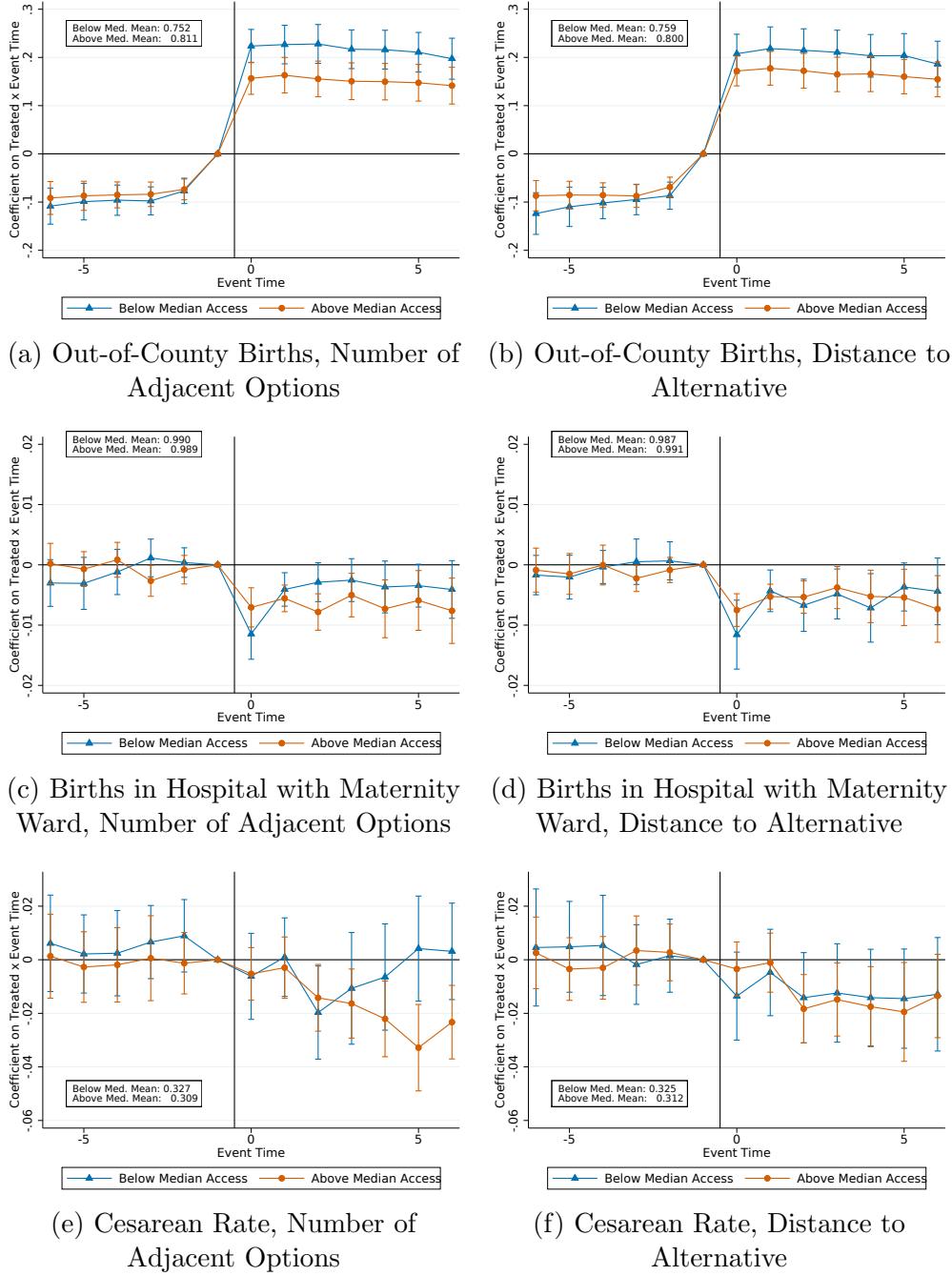
*Note:* Each panel plots the Cesarean rates of closure counties and receiving counties in the years prior to closure. Panel (a) plots the average Cesarean rate of closure counties and receiving counties. Panel (b) plots the average low-risk Cesarean rate of closure counties and receiving counties and Panel (c) plots the average high-risk Cesarean rate of closure counties and receiving counties, where the cutoff for “low” vs. “high” risk is a predicted probability of a Cesarean of 0.30.

Figure 10: Impact of Closure on Cesarean Rates by Initial Differences in Sending and Receiving Counties



*Note:* In Panels (a) - (c), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating Equation (1). The dependent variable in all panels is the share of births delivered via Cesarean. Each panel is estimated on the sample of births where the receiving county has a lower rate of Cesarean birth (Panel (a)), roughly the same rate of Cesarean birth (Panel (b)), or a higher rate of Cesarean birth (Panel (c)). Observations are at the county-event time level and are clustered at the county level.

Figure 11: Estimated Impact of Closure on Selected Outcomes by Access to Alternatives



*Note:* Each point represents the treat-control difference from estimating Equation (1) by above/below median access to alternatives. The dependent variable in Panels (a) - (b) is the share of births occurring out of county, in Panels (c) - (d) is the share of births occurring out of hospital, and in Panels (e) - (f) is the share of births delivered via Cesarean. For each dependent variables, the sample is split above/below median based on access to available alternatives, measured as the number of hospitals with maternity wards in adjacent counties (Panels (a), (c), and (e)) or as the distance to the nearest hospital with a maternity ward (Panels (b), (d), and (f)). Observations are at the county-event time level and are clustered at the county level.

Table 1: Summary Statistics

	(1)	(2)	(3)
	Closure	Never Open	Always Open
Population	22,725	13,987	151,669
% Female 18-44	20.0	19.7	21.7
% Black	8.8	9.6	8.2
% College	19.0	18.3	25.7
Unemployment Rate	6.2	6.2	5.7
Number of Establishments	484	267	3,840
Per Capita Income	17,631	17,198	20,411
Per Capita Transfers	3,626	3,511	3,300
N	414	1,081	1,580

*Note:* This table displays summary statistics for counties that experience a maternity ward closure between 1996 and 2018 (Column 1), counties that are always open between 1996 and 2018 (Column 2), and counties that are never open between 1996 and 2018 (Column 3).

Table 2: Estimated Effects of Closure

	(1)	(2)	(3)
<b>Panel A: Birthing Location</b>			
Share Out-of-County Births [0.787]	0.183*** (0.013)	0.173*** (0.015)	0.178*** (0.014)
Share Out-of-Hospital Births [0.010]	0.002** (0.001)	0.003 (0.002)	0.003** (0.001)
Share In Hospital w/ Maternity [0.990]	-0.009*** (0.001)	-0.005** (0.002)	-0.006** (0.001)
<b>Panel B: Characteristics of Pregnancy and Birth</b>			
Share With One or Fewer Prenatal Visits [0.009]	0.001 (0.001)	0.002 (0.001)	0.001 (0.001)
Share With Low Prenatal Visits ( $\leq$ ) [0.384]	0.023** (0.010)	0.040 (0.026)	0.040** (0.020)
Share Induced [0.269]	0.019*** (0.006)	0.001 (0.017)	0.007 (0.011)
Share C-Section [0.316]	-0.007 (0.004)	-0.019** (0.008)	-0.013*** (0.005)
<b>Panel C: Infant Health</b>			
Share Low Birth Weight [0.083]	-0.003 (0.002)	-0.001 (0.003)	-0.003 (0.002)
Share Apgar Less Than 7 [0.019]	0.001 (0.002)	0.004* (0.002)	0.002 (0.002)
Share Preterm [0.128]	-0.008** (0.003)	-0.006* (0.003)	-0.007** (0.003)
Infant Mortality Rate [0.006]	0.001 (0.001)	0.000 (0.001)	0.000 (0.001)
Observations			
Clusters			
County FE	Yes	Yes	Yes
Event Time FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

*Note:* This table presents results from estimating Equation (1). Each row represents a separate regression with the dependent variable specified in the row. The estimated effects in Columns 1, 2, and 3 correspond to  $\beta_0$ ,  $\beta_5$ , and the post-period average of the  $\beta_\tau$  coefficients. The treatment group's average of the dependent variable in event time  $\tau = -1$  is displayed in brackets. Standard errors are clustered at the county level. Stars report statistical significance: \*\*\* = p-value < 0.01, \*\* = p-value < 0.05, \* = p-value < 0.1.

Table 3: Estimated Effect of Closure on Cesarean Rates by Pregnancy Risk

	(1)	(2)	(3)
Panel A: Below Median Risk			
Estimated Effect [0.164]	-0.002 (0.004)	-0.016* (0.009)	-0.010* (0.005)
Observations	6,680	6,680	6,680
Clusters	292	292	292
Panel B: Above Median Risk			
Estimated Effect [0.774]	-0.014 (0.011)	0.003 (0.013)	0.000 (0.010)
Observations	6,657	6,657	6,657
Clusters	292	292	292
County FE	Yes	Yes	Yes
Event Time FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

*Note:* This table presents results from estimating Equation (1) with the dependent variable being the rate of Cesarean births in a county. Panel A estimates (1) for low-risk women (Predicted Probability of Cesarean  $\leq 0.30$ ) and Panel B estimates (1) for high-risk women ( $PPC > 0.30$ ). The estimated effects in Columns 1, 2, and 3 correspond to  $\beta_0$ ,  $\beta_5$ , and the post-period average of the  $\beta_\tau$  coefficients, respectively. The treatment group's average Cesarean rate in event time  $\tau = -1$  is displayed in brackets. Standard errors are clustered at the county level. Stars report statistical significance: \*\*\* = p-value  $< 0.01$ , \*\* = p-value  $< 0.05$ , \* = p-value  $< 0.1$ .

Table 4: Estimated Effect of Closure on Cesarean Rates by Differences in Closure and Receiving County

	(1)	(2)	(3)
Panel A: Receiving County Has Lower C-Section Rate			
Estimated Effect [0.321]	-0.015** (0.007)	-0.028** (0.011)	-0.022*** (0.008)
Observations	2,254	2,254	2,254
Clusters	98	98	98
Panel B: Receiving County Has Similar C-Section Rate			
Estimated Effect [0.318]	0.008 (0.009)	-0.010 (0.009)	-0.000 (0.007)
Observations	2,205	2,205	2,205
Clusters	96	96	96
Panel C: Receiving County Has Higher C-Section Rate			
Estimated Effect [0.308]	-0.013* (0.008)	-0.009 (0.013)	-0.012 (0.008)
Observations	2,208	2,208	2,208
Clusters	96	96	96
County FE	Yes	Yes	Yes
Event Time FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

*Note:* This table presents results from estimating Equation (1) with the dependent variable being the rate of Cesarean births in a county. Each row represents a separate regression of Equation (1) based on initial differences in Cesarean rates between closure and receiving counties. The estimated effects in Columns 1, 2, and 3 correspond to  $\beta_0$ ,  $\beta_5$ , and the post-period average of the  $\beta_\tau$  coefficients, respectively. The treatment group's average Cesarean rate in event time  $\tau = -1$  is displayed in brackets. Standard errors are clustered at the county level. Stars report statistical significance: \*\*\* = p-value < 0.01, \*\* = p-value < 0.05, \* = p-value < 0.1.

Table 5: Estimated Effects of Closure on Women By Alternatives in Adjacent County

	Above Median Access			Below Median Access		
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Panel A: Birthing Location</b>						
Share Out-of-County Births	0.157*** (0.017) [0.811]	0.147*** (0.019) [0.811]	0.152*** (0.018) [0.811]	0.224*** (0.017) [0.752]	0.211*** (0.021) [0.752]	0.217*** (0.019) [0.752]
Share Out-of-Hospital Births	0.002 (0.001) [0.011]	0.004 (0.003) [0.011]	0.004** (0.002) [0.011]	0.003** (0.001) [0.009]	0.001 (0.002) [0.009]	0.001 (0.001) [0.009]
Share Share In Hospital w/ Maternity	-0.007*** (0.002) [0.989]	-0.006** (0.003) [0.989]	-0.007*** (0.002) [0.989]	-0.011*** (0.002) [0.990]	-0.003* (0.002) [0.990]	-0.005*** (0.001) [0.990]
<b>Panel B: Characteristics of Pregnancy and Birth</b>						
Share With One or Fewer Prenatal Visits	0.001 (0.001) [0.009]	0.002 (0.002) [0.009]	0.000 (0.001) [0.009]	0.001 (0.002) [0.009]	0.003 (0.002) [0.009]	0.003** (0.001) [0.009]
Share With Low Prenatal Visits ( $\leq 10$ )	0.025* (0.014) [0.366]	0.040 (0.033) [0.366]	0.040 (0.025) [0.366]	0.018 (0.013) [0.411]	0.030 (0.026) [0.411]	0.032* (0.018) [0.411]
Share Induced	0.027*** (0.008) [0.258]	0.003 (0.023) [0.258]	0.012 (0.016) [0.258]	0.007 (0.010) [0.284]	-0.000 (0.018) [0.284]	0.002 (0.012) [0.284]
Share C-Section	-0.005 (0.005) [0.309]	-0.033*** (0.008) [0.309]	-0.017*** (0.005) [0.309]	-0.006 (0.008) [0.309]	0.004 (0.010) [0.327]	-0.005 (0.007) [0.327]
<b>Panel C: Infant Health</b>						
Share Low Birth Weight	-0.003 (0.003) [0.079]	-0.003 (0.003) [0.079]	-0.003 (0.003) [0.079]	-0.003 (0.004) [0.088]	0.002 (0.004) [0.088]	-0.002 (0.003) [0.088]
Share Apgar Less Than 7	-0.005 (0.007) [0.020]	-0.002 (0.008) [0.020]	-0.004 (0.007) [0.020]	0.001 (0.002) [0.018]	0.003 (0.003) [0.018]	0.001 (0.002) [0.018]
Share Preterm	-0.005 (0.003) [0.122]	-0.009** (0.004) [0.122]	-0.009*** (0.003) [0.122]	-0.010 (0.007) [0.136]	0.001 (0.006) [0.136]	-0.004 (0.005) [0.136]
Infant Mortality Rate	0.001 (0.001) [0.006]	-0.000 (0.001) [0.006]	0.000 (0.001) [0.006]	0.002 (0.001) [0.007]	0.002 (0.001) [0.007]	0.001 (0.001) [0.007]
Observations	2,990	2,990	2,990	3,722	3,722	3,722
Clusters	130	130	130	162	162	162

*Note:* This table presents results from estimating Equation (1) for women based on their access to alternatives in adjacent county. Each row represents a separate regression of Equation (1) with the dependent variable specified in the row. The sample in columns 1-3 are counties with above-median access and in columns 4-6 are counties with below-median access. The estimated effects in Columns 1/4, 2/5, and 3/6 correspond to  $\beta_0$ ,  $\beta_5$ , and the post-period average of the  $\beta_\tau$  coefficients, respectively. The treatment group's average of the dependent variable in event time  $\tau = -1$  is displayed in brackets. Standard errors are clustered at the county level. Stars report statistical significance: \*\*\* = p-value < 0.01, \*\* = p-value < 0.05, \* = p-value < 0.1.

Table 6: Estimated Effects of Closure on Women By Travel Distance to Nearest Maternity Ward

	Above Median Access			Below Median Access		
	(1)	(2)	(3)	(4)	(5)	(6)
<b>Panel A: Birthing Location</b>						
Share Out-of-County Births	0.172*** (0.016) [0.800]	0.160*** (0.018) [0.800]	0.167*** (0.017) [0.800]	0.208*** (0.020) [0.759]	0.204*** (0.023) [0.759]	0.206*** (0.022) [0.759]
Share Out-of-Hospital Births	0.003*** (0.001) [0.009]	0.004* (0.002) [0.009]	0.004** (0.002) [0.009]	0.001 (0.002) [0.013]	-0.001 (0.002) [0.013]	0.001 (0.002) [0.013]
Share Share In Hospital w/ Maternity	-0.008*** (0.001) [0.991]	-0.005** (0.002) [0.991]	-0.006*** (0.002) [0.991]	-0.012*** (0.003) [0.987]	-0.004* (0.002) [0.987]	-0.006*** (0.002) [0.987]
<b>Panel B: Characteristics of Pregnancy and Birth</b>						
Share With One or Fewer Prenatal Visits	0.002 (0.001) [0.008]	0.001 (0.002) [0.008]	0.001 (0.001) [0.008]	0.000 (0.002) [0.011]	0.005 (0.003) [0.011]	0.003** (0.001) [0.011]
Share With Low Prenatal Visits ( $\leq 10$ )	0.030*** (0.012) [0.362]	0.038 (0.035) [0.362]	0.042* (0.025) [0.362]	0.001 (0.016) [0.435]	0.044* (0.026) [0.435]	0.031 (0.020) [0.435]
Share Induced	0.019** (0.008) [0.263]	-0.006 (0.021) [0.263]	0.006 (0.014) [0.263]	0.019* (0.010) [0.280]	0.018 (0.017) [0.280]	0.011 (0.013) [0.280]
Share C-Section	-0.003 (0.005) [0.312]	-0.019** (0.009) [0.312]	-0.013** (0.006) [0.312]	-0.014 (0.008) [0.325]	-0.015 (0.009) [0.325]	-0.012* (0.007) [0.325]
<b>Panel C: Infant Health</b>						
Share Low Birth Weight	-0.003 (0.003) [0.083]	-0.003 (0.003) [0.083]	-0.004 (0.002) [0.083]	-0.001 (0.005) [0.084]	0.004 (0.005) [0.084]	0.000 (0.004) [0.084]
Share Apgar Less Than 7	0.001 (0.001) [0.018]	0.004 (0.003) [0.018]	0.002 (0.002) [0.018]	0.002 (0.004) [0.024]	0.002 (0.004) [0.024]	0.000 (0.003) [0.024]
Share Preterm	-0.007* (0.004) [0.127]	-0.009** (0.004) [0.127]	-0.010*** (0.003) [0.127]	-0.008 (0.006) [0.128]	0.003 (0.006) [0.128]	-0.000 (0.004) [0.128]
Infant Mortality Rate	0.001 (0.001) [0.006]	-0.000 (0.001) [0.006]	0.000 (0.001) [0.006]	0.001 (0.001) [0.007]	0.001 (0.001) [0.007]	0.001 (0.001) [0.007]
Observations	3,401	3,401	3,401	3,311	3,311	3,311
Clusters	148	148	148	144	144	144

*Note:* This table presents results from estimating Equation (1) for women based on their travel distance to the closest maternity ward following closure. Each row represents a separate regression of Equation (1) with the dependent variable specified in the row. The sample in columns 1-3 are counties with above-median access and in columns 4-6 are counties with below-median access. The estimated effects in Columns 1/4, 2/5, and 3/6 correspond to  $\beta_0$ ,  $\beta_5$ , and the post-period average of the  $\beta_\tau$  coefficients, respectively. The treatment group's average of the dependent variable in event time  $\tau = -1$  is displayed in brackets. Standard errors are clustered at the county level. Stars report statistical significance: \*\*\* = p-value < 0.01, \*\* = p-value < 0.05, \* = p-value < 0.1.

Table 7: Estimated Effects of Closure on Women in Receiving Counties

	(1)	(2)	(3)
Panel A: Birthing Location			
Share Out-of-County Births [0.098]	-0.015 (0.010)	0.012 (0.012)	-0.002 (0.009)
Share Out-of-Hospital Births [0.006]	-0.000 (0.001)	-0.000 (0.001)	-0.000 (0.001)
Share In Hospital w/ Maternity [0.994]	0.001 (0.001)	0.005** (0.002)	0.004 (0.001)
Panel B: Characteristics of Pregnancy and Birth			
Share With One or Fewer Prenatal Visits [0.009]	0.003 (0.002)	0.002 (0.002)	0.002 (0.002)
Share With Low Prenatal Visits ( $\leq 10$ ) [0.384]	0.002 (0.009)	0.039 (0.042)	0.027 (0.028)
Share Induced [0.275]	0.009 (0.014)	0.010 (0.016)	0.012 (0.013)
Share C-Section [0.282]	0.005 (0.006)	0.011 (0.012)	0.012 (0.010)
Panel C: Infant Health			
Share Low Birth Weight [0.086]	-0.001 (0.002)	0.000 (0.003)	0.002 (0.002)
Share Apgar Less Than 7 [0.018]	-0.000 (0.002)	0.002 (0.004)	0.002 (0.003)
Share Preterm [0.135]	-0.004 (0.003)	-0.008** (0.004)	-0.004 (0.003)
Infant Mortality Rate [0.006]	-0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
Observations	3,542	3,542	3,542
Clusters	154	154	154
County FE	Yes	Yes	Yes
Event Time FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

*Note:* This table presents results from estimating Equation (1) for women residing in receiving counties as described in the text. Each row represents a separate regression of Equation (1) with the dependent variable specified in the row. The estimated effects in Columns 1, 2, and 3 correspond to  $\beta_0$ ,  $\beta_5$ , and the post-period average of the  $\beta_\tau$  coefficients, respectively. The treatment group's average of the dependent variable in event time  $\tau = -1$  is displayed next to the dependent variable in brackets. Standard errors are clustered at the county level. Stars report statistical significance: \*\*\* = p-value < 0.01, \*\* = p-value < 0.05, \* = p-value < 0.1.

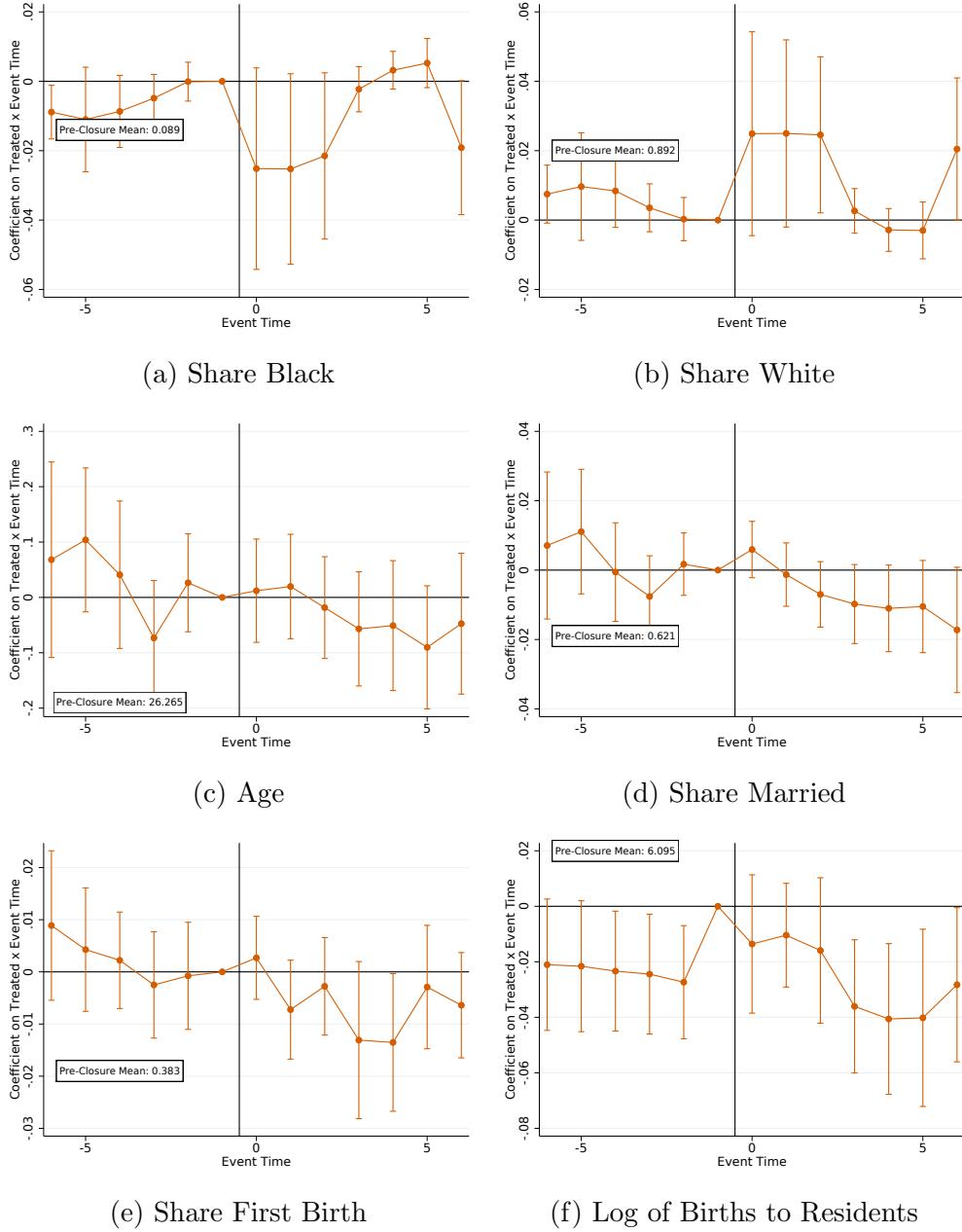
Table 8: Estimated Effects of Closure on Women By Demographic Subgroup

	US-Born Black (1)	US-Born Hispanic (2)	High School & Below (3)	College & Above (4)	Less Than 20 Years (5)	More Than 35 Years (6)
Panel A: Birthing Location						
Share Out-of-County Births	0.281*** (0.048) [0.672]	0.128*** (0.019) [0.841]	0.143*** (0.019) [0.781]	0.040** (0.015) [0.909]	0.158*** (0.023) [0.740]	0.081*** (0.016) [0.839]
Share Out-of-Hospital Births	0.005*** (0.001) [0.002]	0.003 (0.003) [0.005]	-0.007 (0.004) [0.012]	-0.003 (0.004) [0.010]	0.003** (0.001) [0.002]	-0.006 (0.004) [0.023]
Share In Hospital w/ Maternity	-0.010*** (0.002) [0.996]	-0.011** (0.005) [0.994]	-0.008*** (0.002) [0.987]	-0.005*** (0.002) [0.990]	-0.006*** (0.002) [0.996]	-0.004 (0.003) [0.977]
Panel B: Characteristics of Pregnancy and Birth						
Share With One or Fewer Prenatal Visits	0.004 (0.004) [0.017]	0.004 (0.003) [0.007]	0.001 (0.002) [0.015]	0.001 (0.001) [0.003]	0.002 (0.002) [0.011]	-0.000 (0.002) [0.009]
Share With Low Prenatal Visits ( $\leq 10$ )	0.058* (0.035) [0.469]	0.103*** (0.029) [0.473]	0.037* (0.020) [0.452]	0.077** (0.031) [0.293]	0.029 (0.020) [0.463]	0.058** (0.028) [0.381]
Share Induced	0.026 (0.020) [0.227]	0.060** (0.026) [0.244]	0.023** (0.011) [0.277]	0.014 (0.013) [0.277]	0.033*** (0.012) [0.294]	0.022 (0.017) [0.242]
Share Cesarean	-0.021* (0.012) [0.332]	-0.004 (0.014) [0.303]	0.000 (0.005) [0.299]	-0.005 (0.008) [0.331]	-0.014** (0.006) [0.249]	-0.010 (0.010) [0.413]
Panel C: Infant Health						
Share Low Birth Weight	0.009 (0.008) [0.148]	-0.014** (0.007) [0.095]	-0.001 (0.002) [0.092]	-0.003 (0.003) [0.066]	0.001 (0.004) [0.094]	-0.005 (0.004) [0.100]
Share Apgar Less Than 7	0.008 (0.006) [0.030]	-0.003 (0.007) [0.028]	0.003 (0.002) [0.022]	-0.003 (0.005) [0.018]	0.001 (0.003) [0.024]	0.005 (0.004) [0.023]
Share Preterm	-0.002 (0.008) [0.198]	-0.017*** (0.005) [0.142]	-0.001 (0.004) [0.135]	-0.006 (0.004) [0.108]	0.001 (0.004) [0.138]	-0.003 (0.006) [0.155]
Infant Mortality Rate	0.005* (0.002) [0.010]	-0.003* (0.001) [0.011]	0.000 (0.001) [0.006]	-0.001 (0.001) [0.004]	-0.000 (0.001) [0.007]	-0.001 (0.001) [0.008]
Observations	2,367	2,546	5,789	5,795	6,293	6,332
Clusters	104	112	252	252	274	276

Note: This table presents results from estimating Equation (1) for women based on their demographic subgroup. Each coefficient represents the  $\beta_\tau$  coefficient from a separate regression with the dependent variable specified in the row and the sample specified in the column. The treatment group's average of the dependent variable in event time  $\tau = -1$  is displayed in brackets. Standard errors are clustered at the county level. Stars report statistical significance: \*\*\* = p-value < 0.01, \*\* = p-value < 0.05, \* = p-value < 0.1.

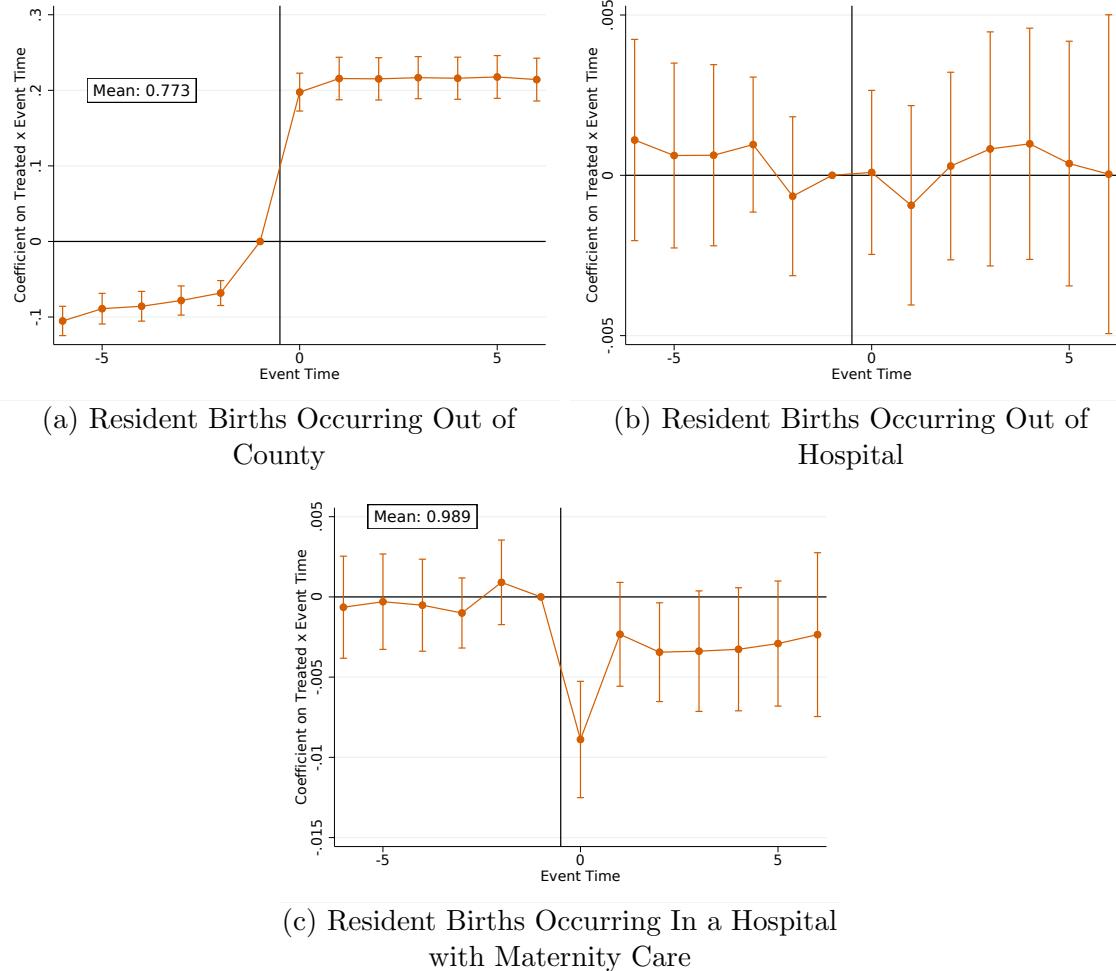
## Appendix A Additional Results

Figure A1: Estimated Impact of Closure on Composition



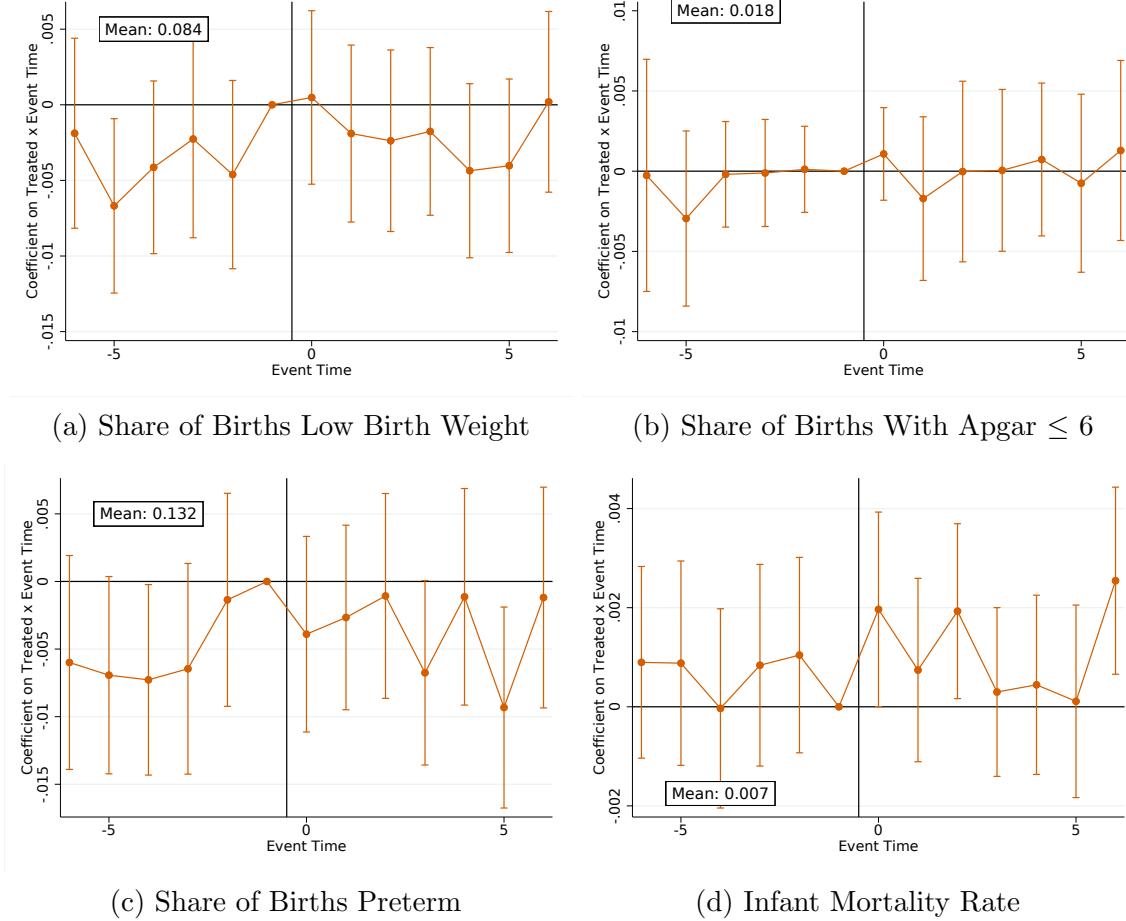
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the share of births to Black women (Panel (a)), the share of births to white women (Panel (b)), age at birth (Panel (c)), the share of births to married women (Panel (d)), the share of first births (Panel (e)), and the log of births to residents of a county (Panel (f)). Observations are at the county-event time level and are clustered at the county level.

Figure A2: Estimated Impact of Closure on County Births, Control Never Provided Maternity Care



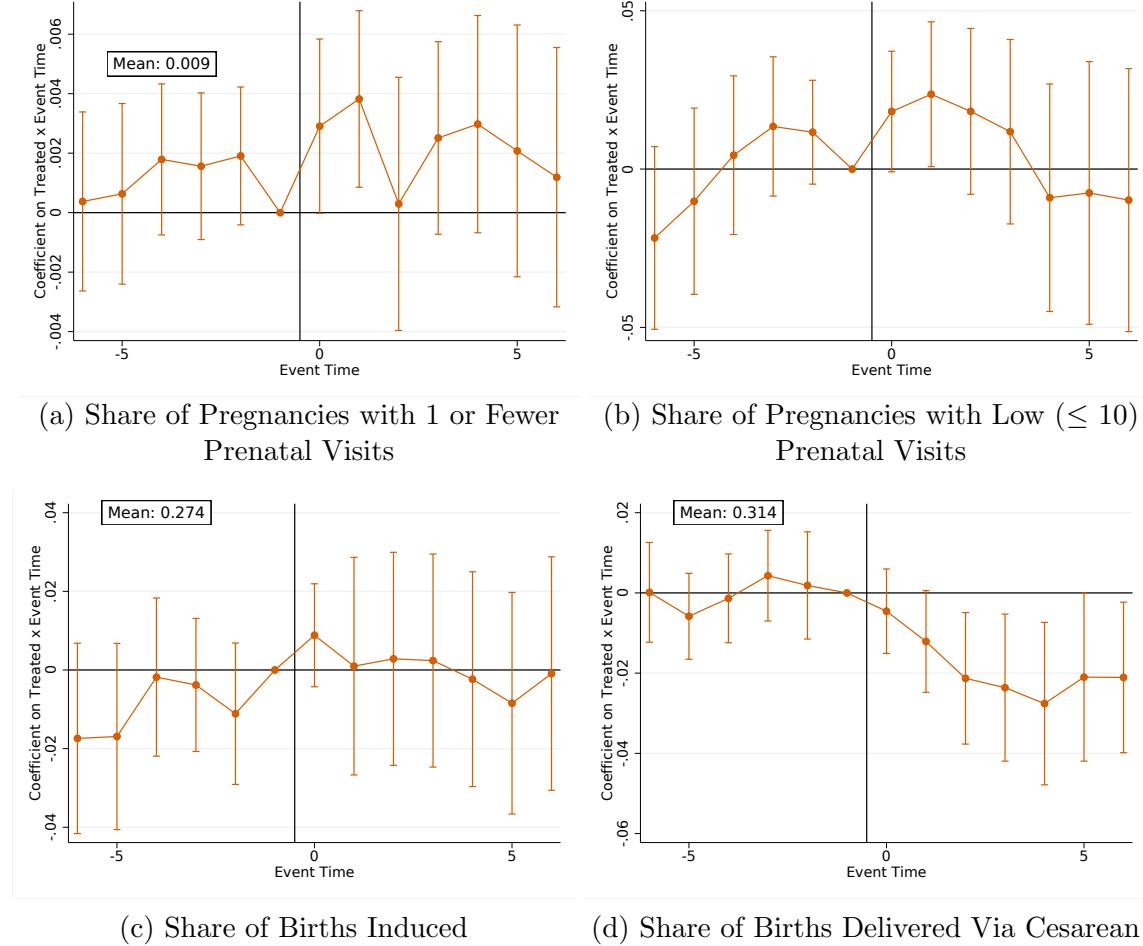
*Note:* In Panels (a) - (c), each point, and the associated 95 percent confidence interval, represents the treatment-control difference from estimating Equation (1). The dependent variable in Panel (a) is the share of births occurring to residents of a county occurring outside of the residence county, in Panel (b) is the share of births occurring outside of a hospital, and in Panel (c) is the share of births occurring in a hospital with an active maternity ward. Observations are at the county-event time level and are clustered at the county level. The control counties are selected from counties that never provided maternity services from 1996 to 2018.

Figure A3: Estimated Impact of Closure on Infant Health, Control Never Provided Maternity Care



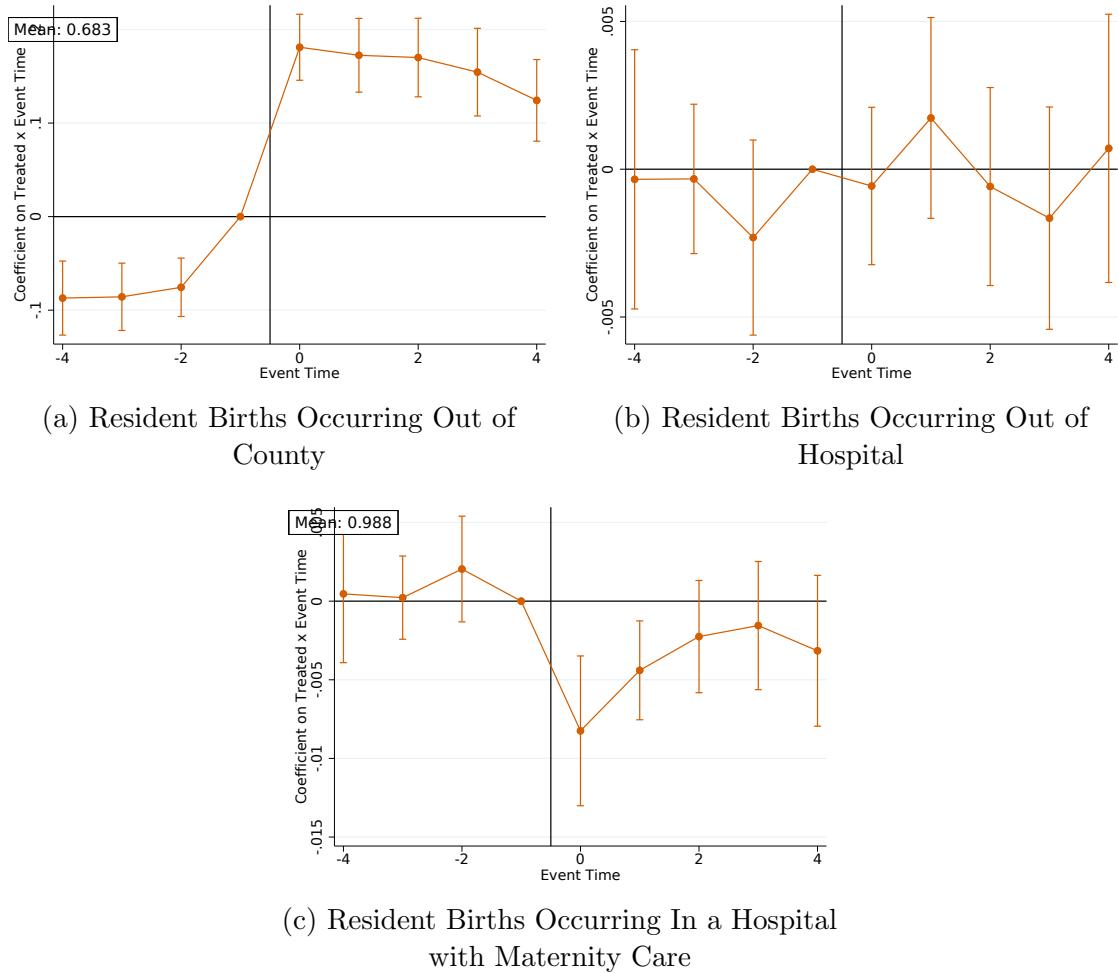
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births low birth weight ( $< 2500$  grams), in Panel (b) is the share of births with an Apgar score less than or equal to 6, in Panel (c) is the share of births preterm ( $< 37$  weeks gestation), and in Panel (d) is the infant mortality rate. Observations are at the county-event time level and are clustered at the county level. The control counties are selected from counties that never provided maternity services from 1996 to 2018.

Figure A4: Estimated Impact of Closure on Characteristics of Pregnancy and Birth,  
Control Never Provided Maternity Care



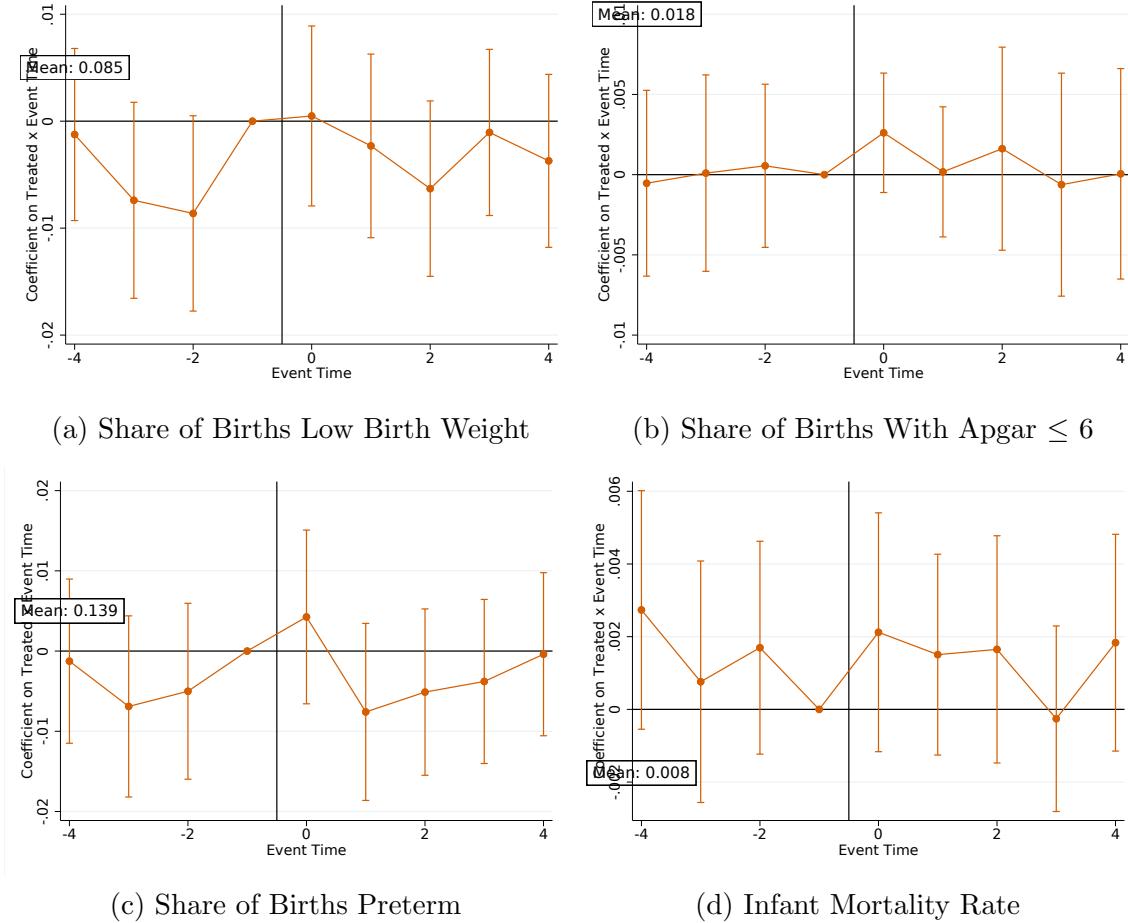
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births occurring outside of a hospital, in Panel (b) is the share of pregnancies with one or fewer prenatal visits, in Panel (c) is the share of births induced, and in Panel (d) is the share of deliveries that occur via a Cesarean. Observations are at the county-event time level and are clustered at the county level. The control counties are selected from counties that never provided maternity services from 1996 to 2018.

Figure A5: Estimated Impact of Closure on County Births, Control Closes Later



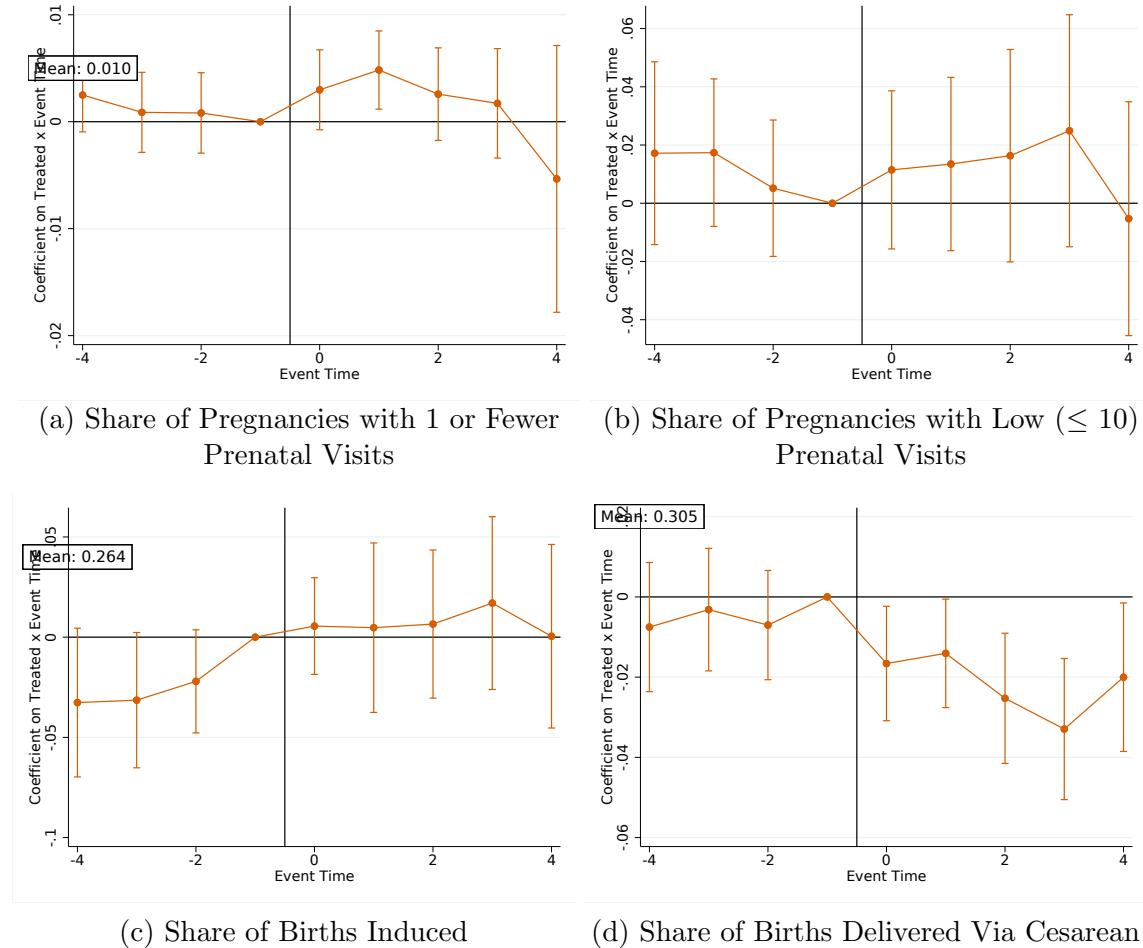
*Note:* In Panels (a) and (b), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the number of births occurring within a county at event time  $\tau$  and in Panel (b) is the share of births occurring to residents of a county occurring outside of the residence county. Observations are at the county-event time level and are clustered at the county level. The control counties are selected from counties that close within a state at least four years later.

Figure A6: Estimated Impact of Closure on Infant Health, Control Closes Later



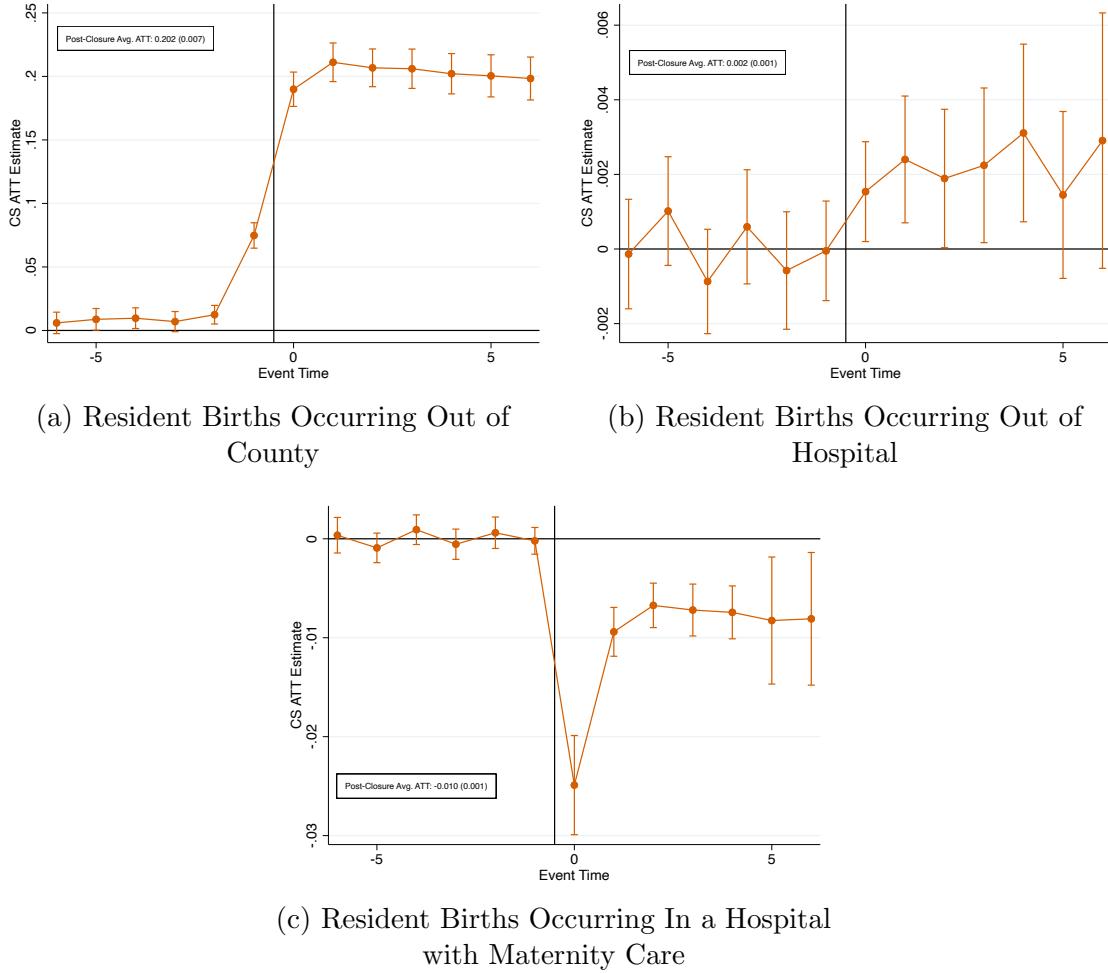
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births low birth weight (< 2500 grams), in Panel (b) is the share of births with an Apgar score less than or equal to 6, in Panel (c) is the share of births preterm (< 37 weeks gestation), and in Panel (d) is the infant mortality rate. Observations are at the county-event time level and are clustered at the county level. The control counties are selected from counties that close within a state at least four years later.

Figure A7: Estimated Impact of Closure on Characteristics of Pregnancy and Birth,  
Control Closes Later



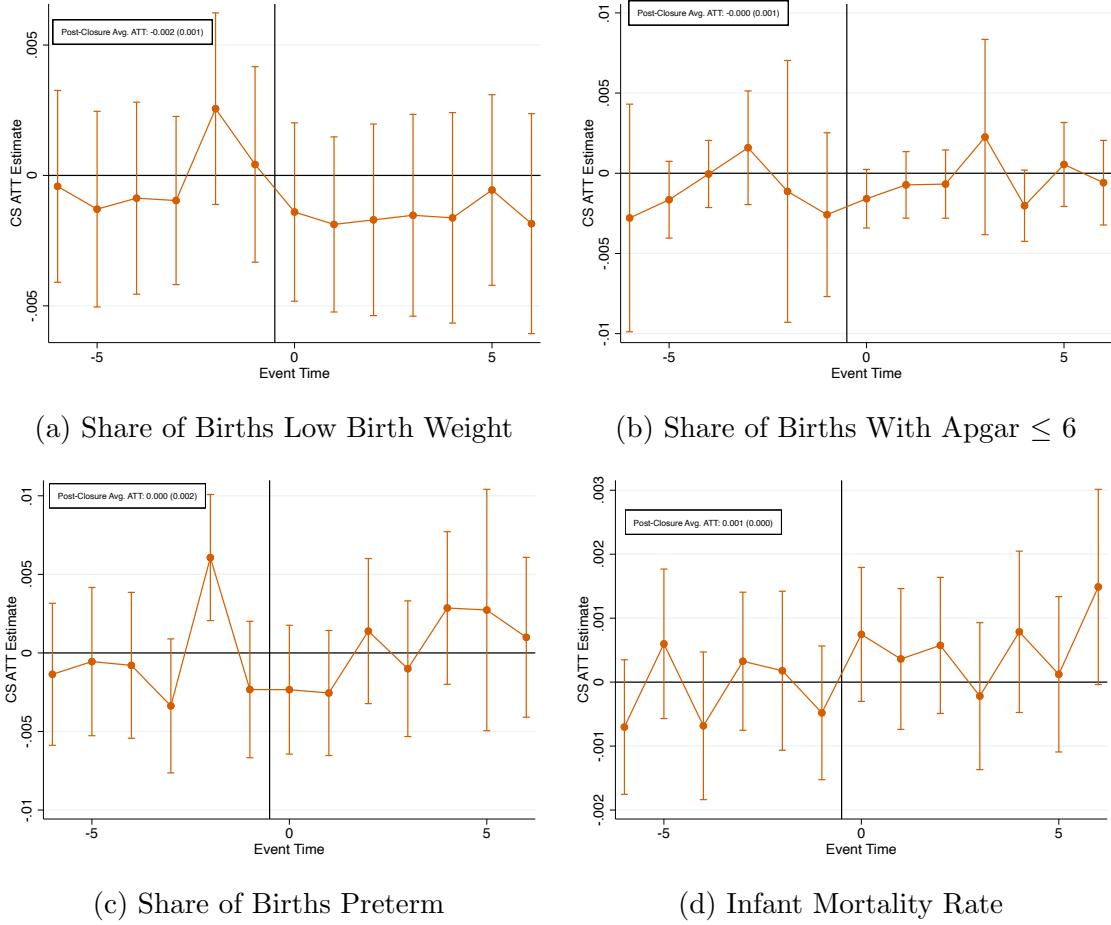
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births occurring outside of a hospital, in Panel (b) is the share of pregnancies with one or fewer prenatal visits, in Panel (c) is the share of births induced, and in Panel (d) is the share of deliveries that occur via a Cesarean. Observations are at the county-event time level and are clustered at the county level. The control counties are selected from counties that close within a state at least four years later.

Figure A8: Estimated Impact of Closure on County Births, Callaway and Sant'Anna Estimator



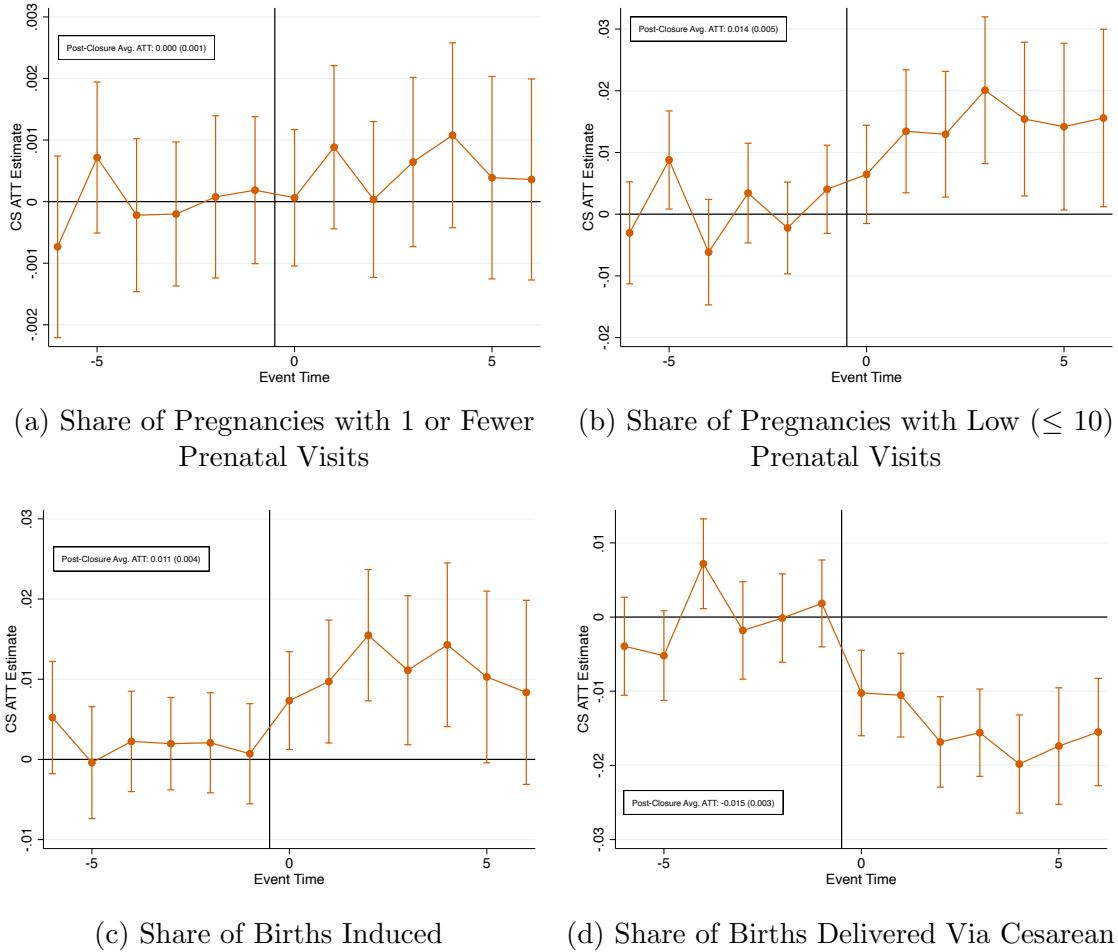
*Note:* In Panels (a) and (b), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1) using the [Callaway and Sant'Anna \(2021\)](#) estimator. The dependent variable in Panel (a) is the number of births occurring within a county at event time  $\tau$  and in Panel (b) is the share of births occurring to residents of a county occurring outside of the residence county. Observations are at the county-event time level and are clustered at the county level. The aggregate ATT for the post-period is displayed in the box.

Figure A9: Estimated Impact of Closure on Infant Health, Callaway and Sant'Anna Method



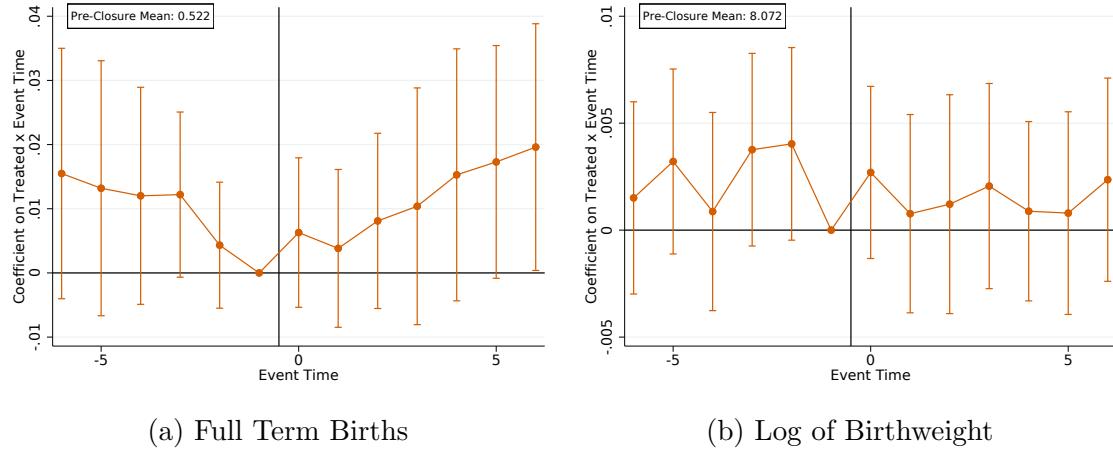
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1) using the [Callaway and Sant'Anna \(2021\)](#) estimator. The dependent variable in Panel (a) is the share of births low birth weight (< 2500 grams), in Panel (b) is the share of births with an Apgar score less than or equal to 6, in Panel (c) is the share of births preterm (< 37 weeks gestation), and in Panel (d) is the infant mortality rate. Observations are at the county-event time level and are clustered at the county level. The aggregate ATT for the post-period is displayed in the box.

Figure A10: Estimated Impact of Closure on Characteristics of Pregnancy and Birth,  
Callaway and Sant'Anna Method



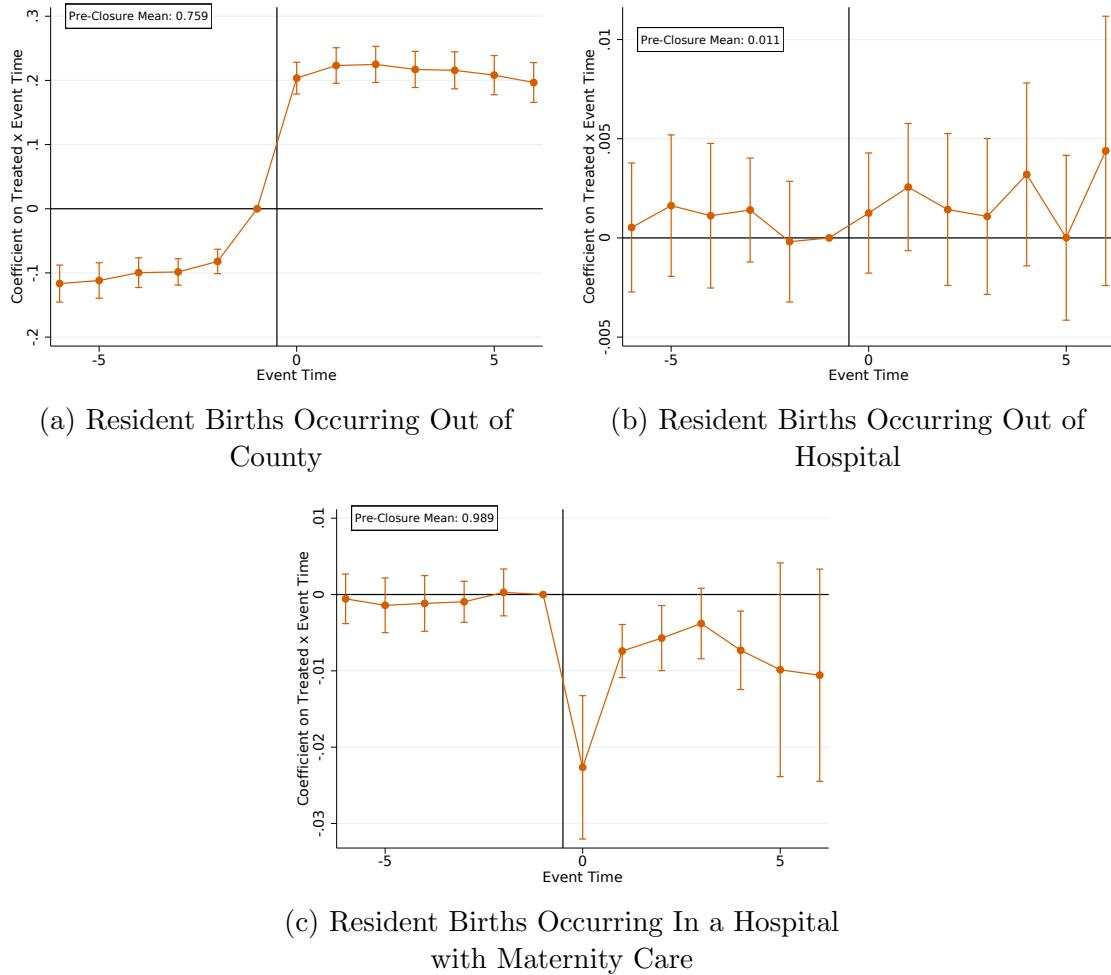
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1) using the [Callaway and Sant'Anna \(2021\)](#) estimator. The dependent variable in Panel (a) is the share of births occurring outside of a hospital, in Panel (b) is the share of pregnancies with one or fewer prenatal visits, in Panel (c) is the share of births induced, and in Panel (d) is the share of deliveries that occur via a Cesarean. Observations are at the county-event time level and are clustered at the county level. The aggregate ATT for the post-period is displayed in the box.

Figure A11: Estimated Impact of Closure on Additional Outcomes



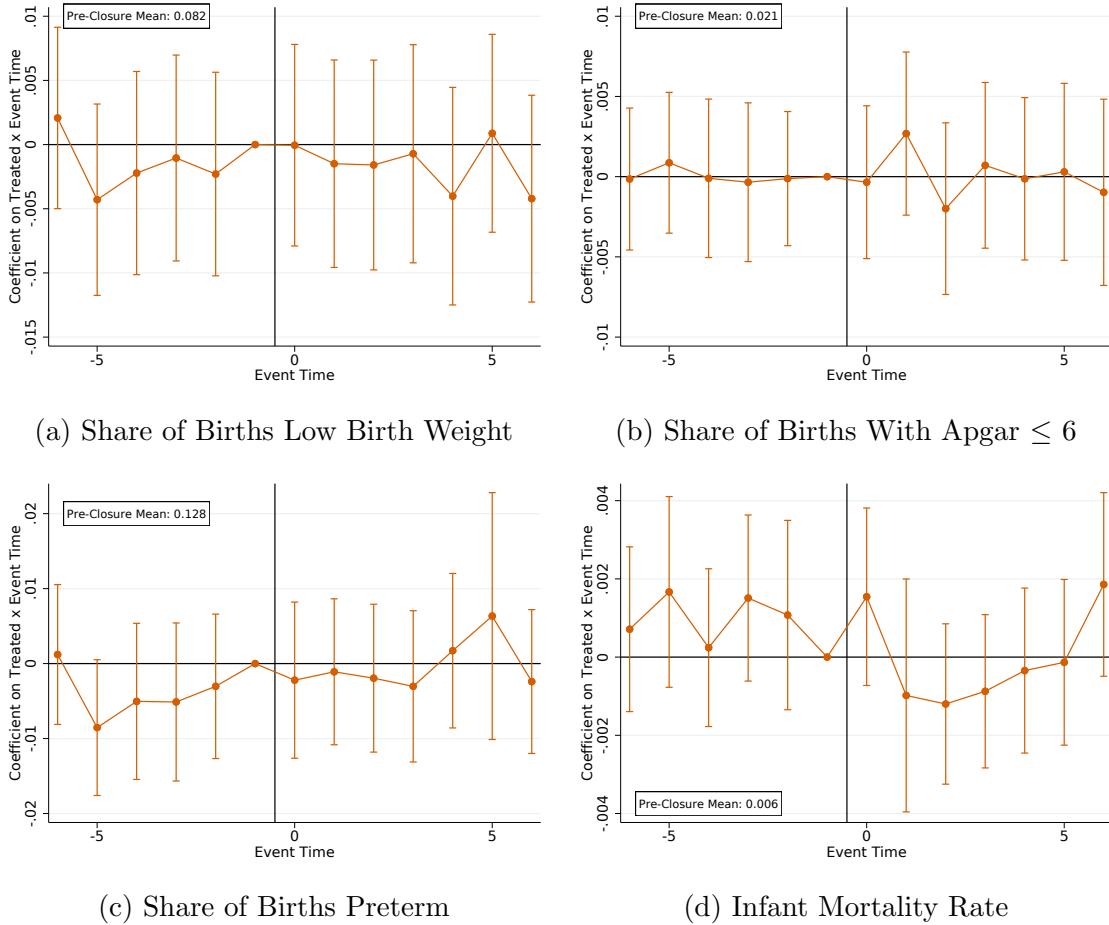
*Note:* In Panels (a) and (b), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births born full-term (between 39 weeks and 0 days gestation and 41 weeks and 6 days gestation), in Panel (b) is the log of birthweight. Observations are at the county-event time level and are clustered at the county level.

Figure A12: Estimated Impact of Closure on County Births, Unweighted



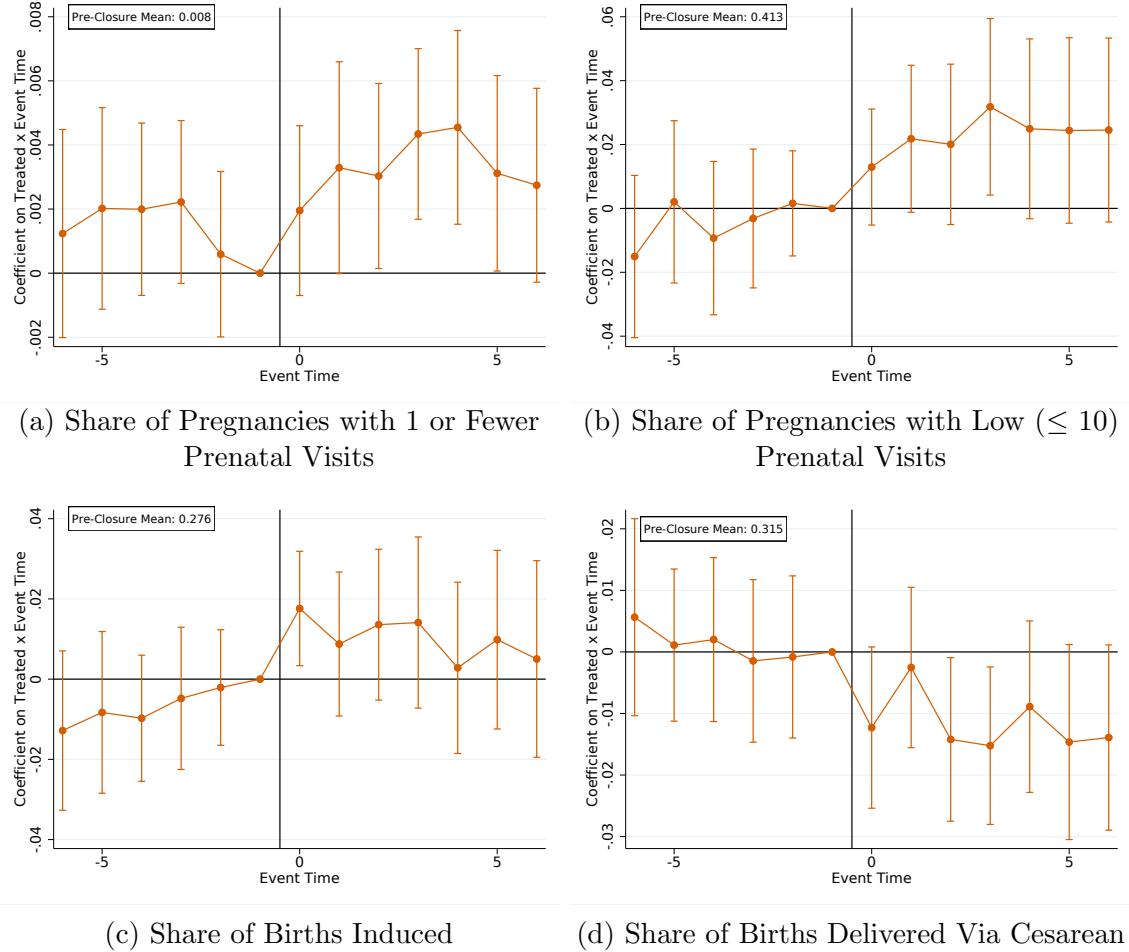
Note: In Panels (a) - (c), each point, and the associated 95 percent confidence interval, represents the treatment-control difference from estimating Equation (1). The dependent variable in Panel (a) is the share of births occurring to residents of a county occurring outside of the residence county, in Panel (b) is the share of births occurring outside of a hospital, and in Panel (c) is the share of births occurring in a hospital with an active maternity ward. Observations are at the county-event time level and are clustered at the county level.

Figure A13: Estimated Impact of Closure on Infant Health, Unweighted



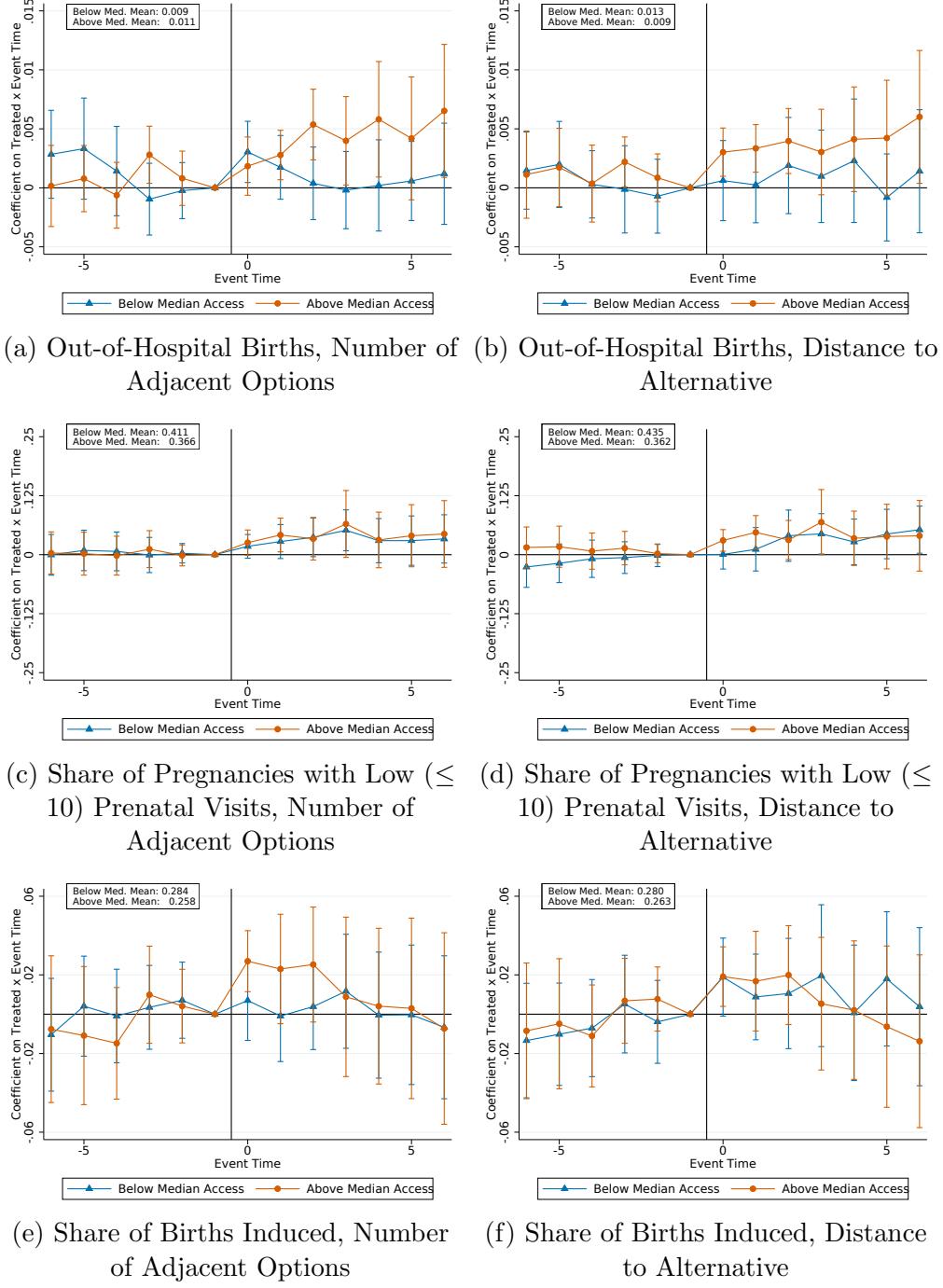
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births low birth weight ( $< 2500$  grams), in Panel (b) is the share of births born with an Apgar score of 6 or below, in Panel (c) is the share of births preterm ( $< 37$  weeks gestation), and in Panel (d) is the infant mortality rate. Observations are at the county-event time level and are clustered at the county level.

Figure A14: Estimated Impact of Closure on Characteristics of Pregnancy and Birth,  
Unweighted



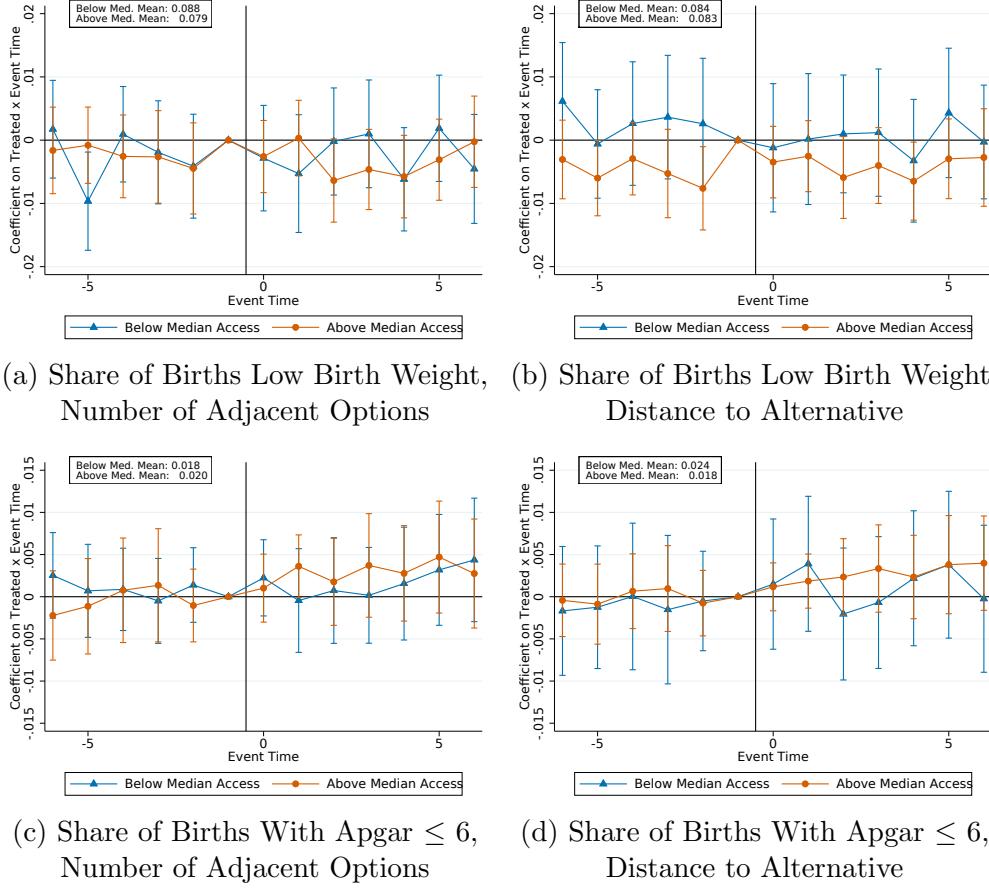
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births occurring outside of a hospital, in Panel (b) is the share of pregnancies with one or fewer prenatal visits, in Panel (c) is the share of births induced, and in Panel (d) is the share of deliveries that occur via a Cesarean. Observations are at the county-event time level and are clustered at the county level.

Figure A15: Estimated Impact of Closure by Access to Alternatives



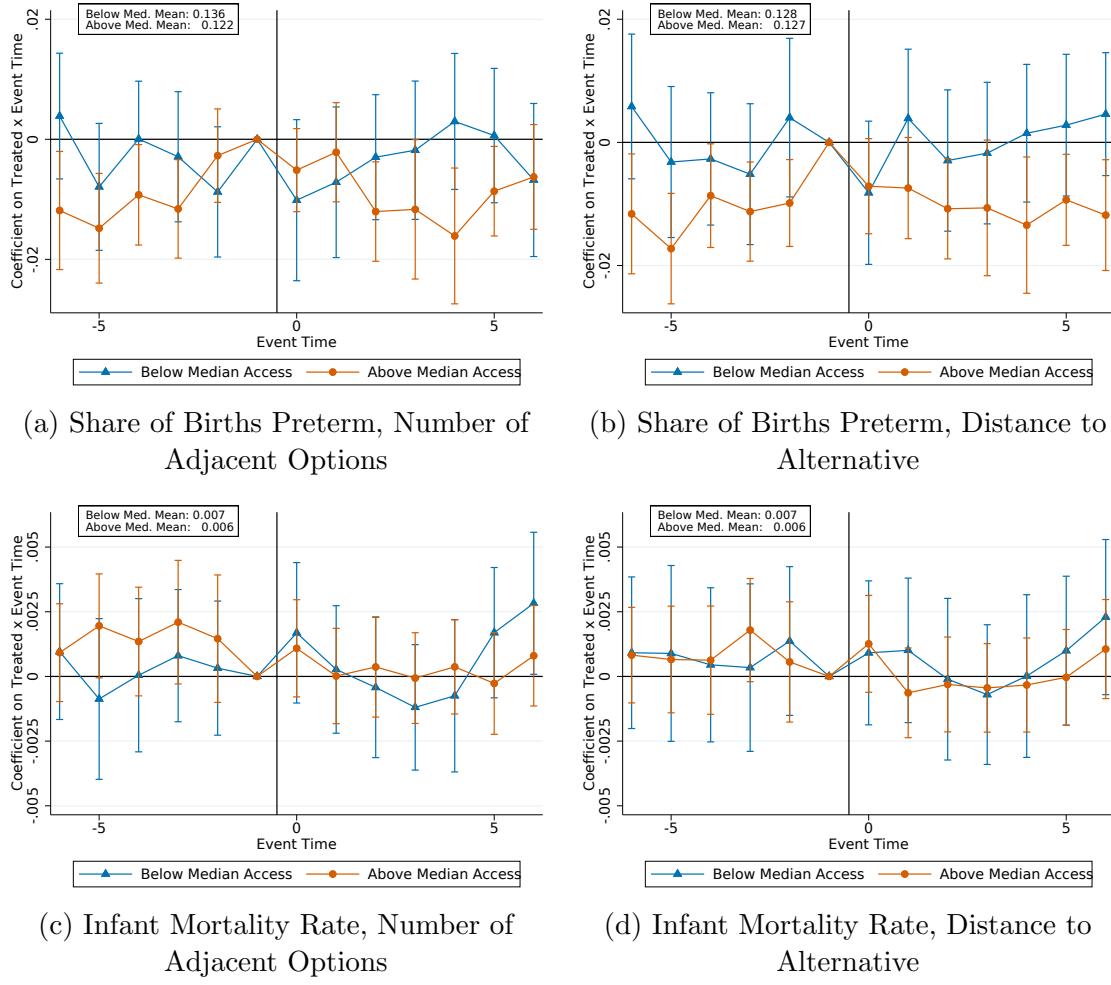
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1) by above/below median access to alternatives. The dependent variable in Panels (a) - (b) is the number of births occurring outside of a hospital, in Panels (c) - (d) is the share of pregnancies with 10 or fewer prenatal visits, and in Panels (e) - (f) is the share of births induced. For each dependent variables, the sample is split above/below median based on access to available alternatives, measured as the number of hospitals with maternity wards in adjacent counties (Panels (a), (c), and (e)) or as the distance to the nearest hospital with a maternity ward (Panels (b), (d), and (f)). Observations are at the county-event time level and are clustered at the county level.

Figure A16: Estimated Impact of Closure by Access to Alternatives



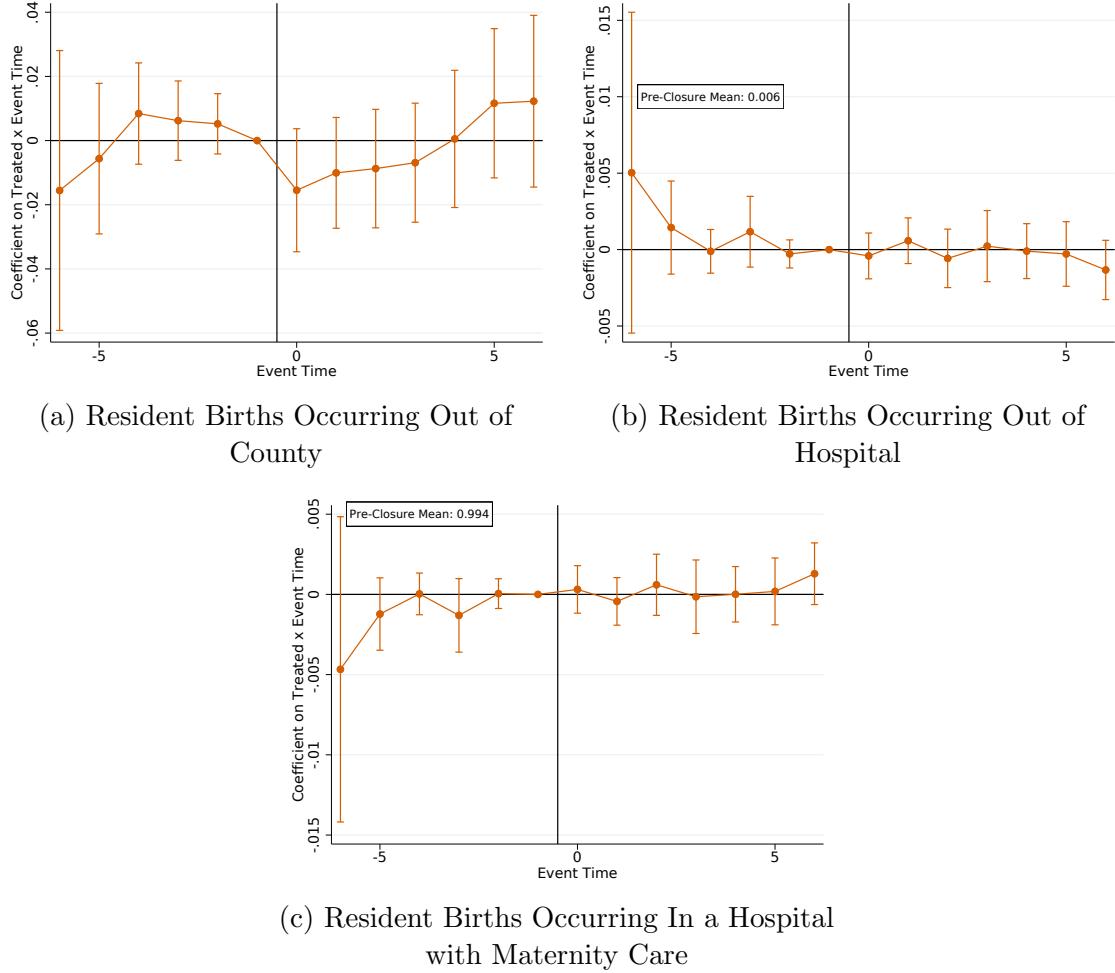
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1) by above/below median access to alternatives. The dependent variable in Panels (a) - (b) is the share of births low birth weight and in Panels (c) - (d) is the share of births with an Apgar score less than or equal to 6. For each dependent variables, the sample is split above/below median based on access to available alternatives, measured as the number of hospitals with maternity wards in adjacent counties (Panels (a) and (c)) or as the distance to the nearest hospital with a maternity ward (Panels (b) and (d)). Observations are at the county-event time level and are clustered at the county level.

Figure A17: Estimated Impact of Closure by Access to Alternatives



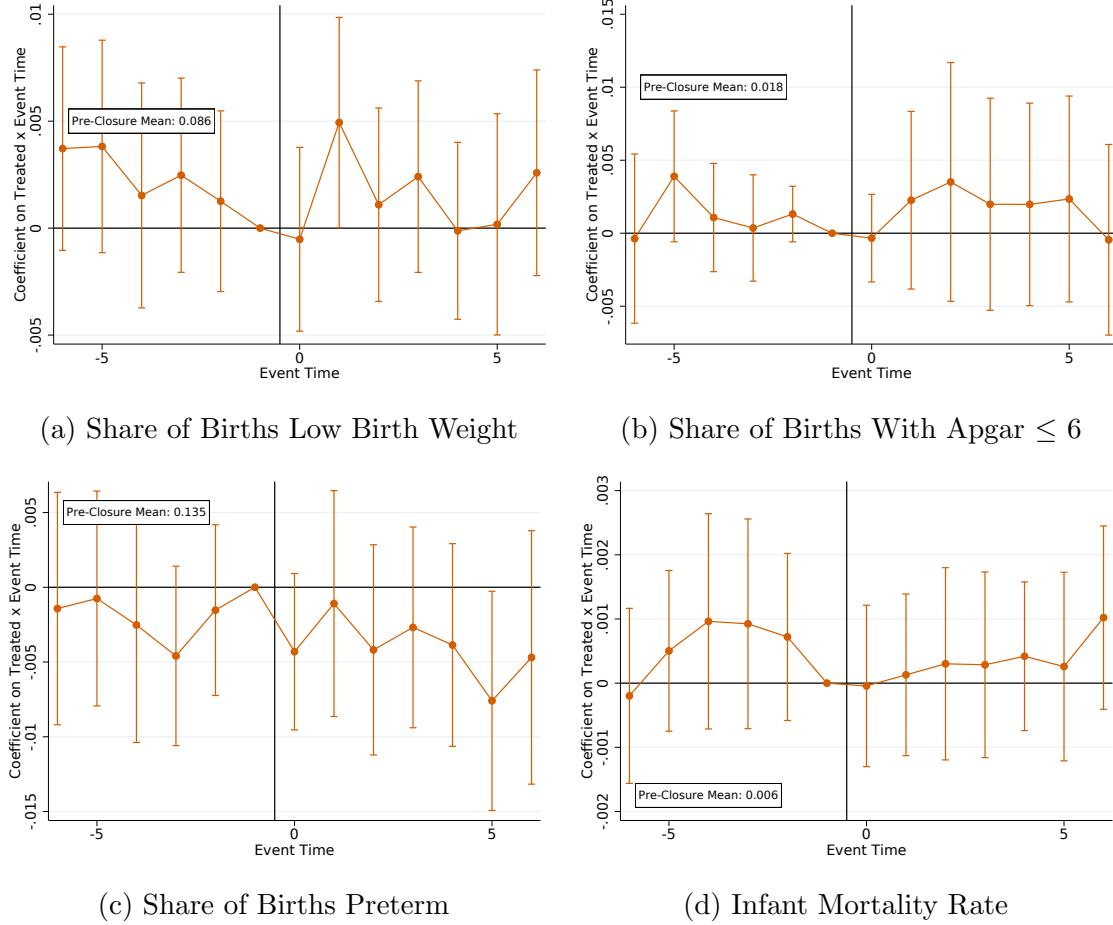
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1) by above/below median access to alternatives. The dependent variable in Panels (a) - (b) is the share of births preterm and in Panels (c) - (d) is the infant mortality rate. For each dependent variables, the sample is split above/below median based on access to available alternatives, measured as the number of hospitals with maternity wards in adjacent counties (Panels (a) and (c)) or as the distance to the nearest hospital with a maternity ward (Panels (b) and (d)). Observations are at the county-event time level and are clustered at the county level.

Figure A18: Estimated Impact of Closure on County Births in Receiving Counties



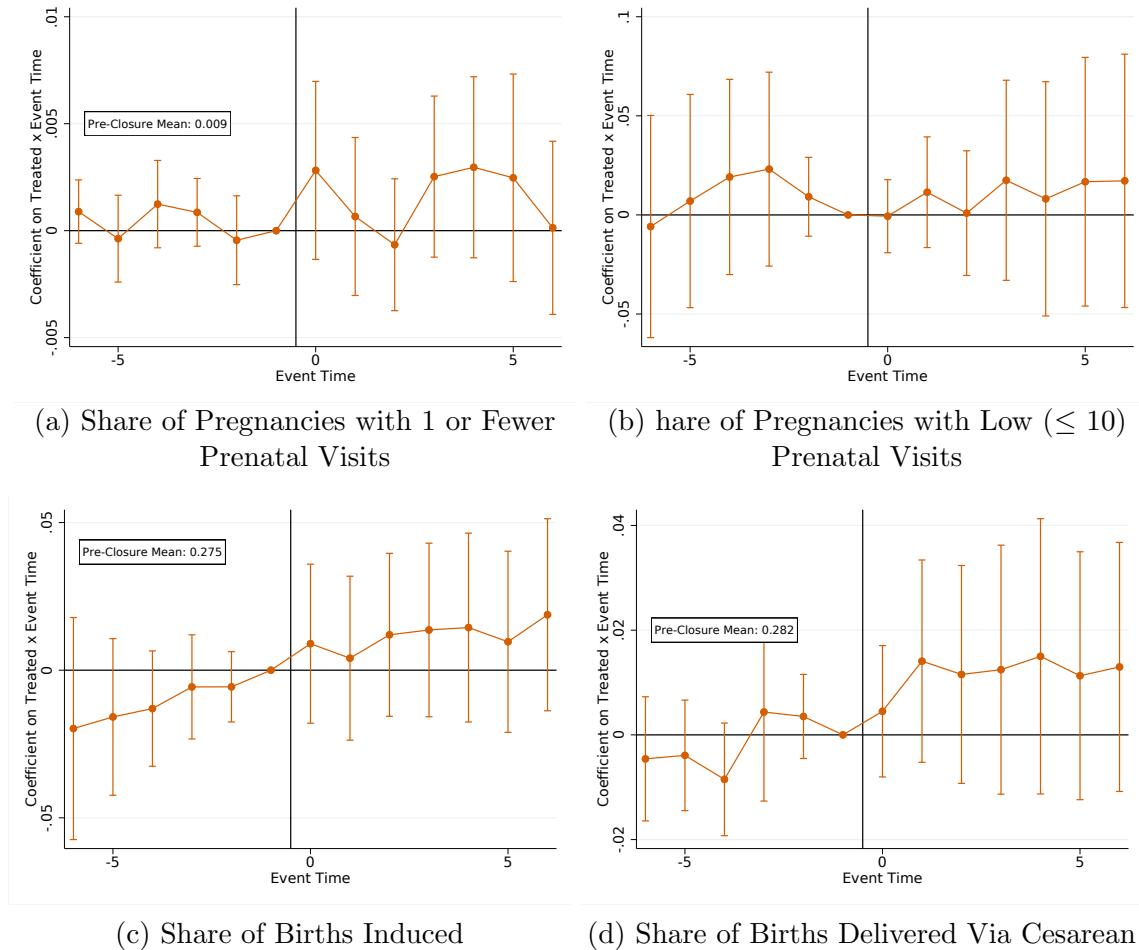
*Note:* In Panels (a) - (c), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating Equation (1). The dependent variable in Panel (a) is the share of births occurring to residents of a county occurring outside of the residence county, in Panel (b) is the share of births occurring outside of a hospital, and in Panel (c) is the share of births occurring in a hospital with an active maternity ward. The sample consists of “receiving counties” as described in the text. Observations are at the county-event time level and are clustered at the county level.

Figure A19: Estimated Impact of Closure on Infant Health in Receiving Counties



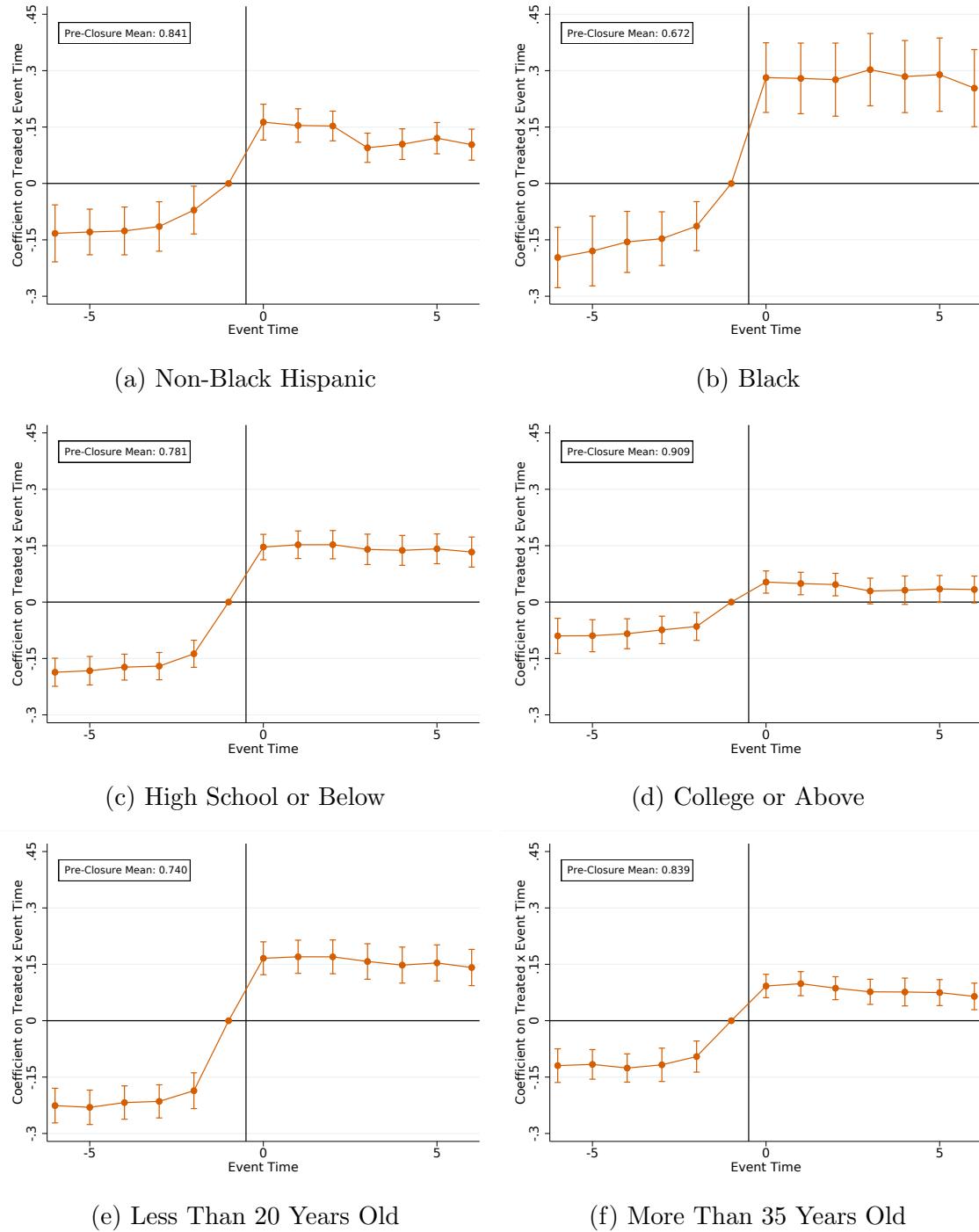
Note: In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treatment-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births low birth weight (< 2500 grams), in Panel (b) is the share of births with an Apgar score of 6 or below, in Panel (c) is the share of births preterm (< 37 weeks gestation), and in Panel (d) is the infant mortality rate. The sample consists of “receiving counties” as described in the text. Observations are at the county-event time level and are clustered at the county level.

Figure A20: Estimated Impact of Closure on Characteristics of Pregnancy and Birth in Receiving Counties



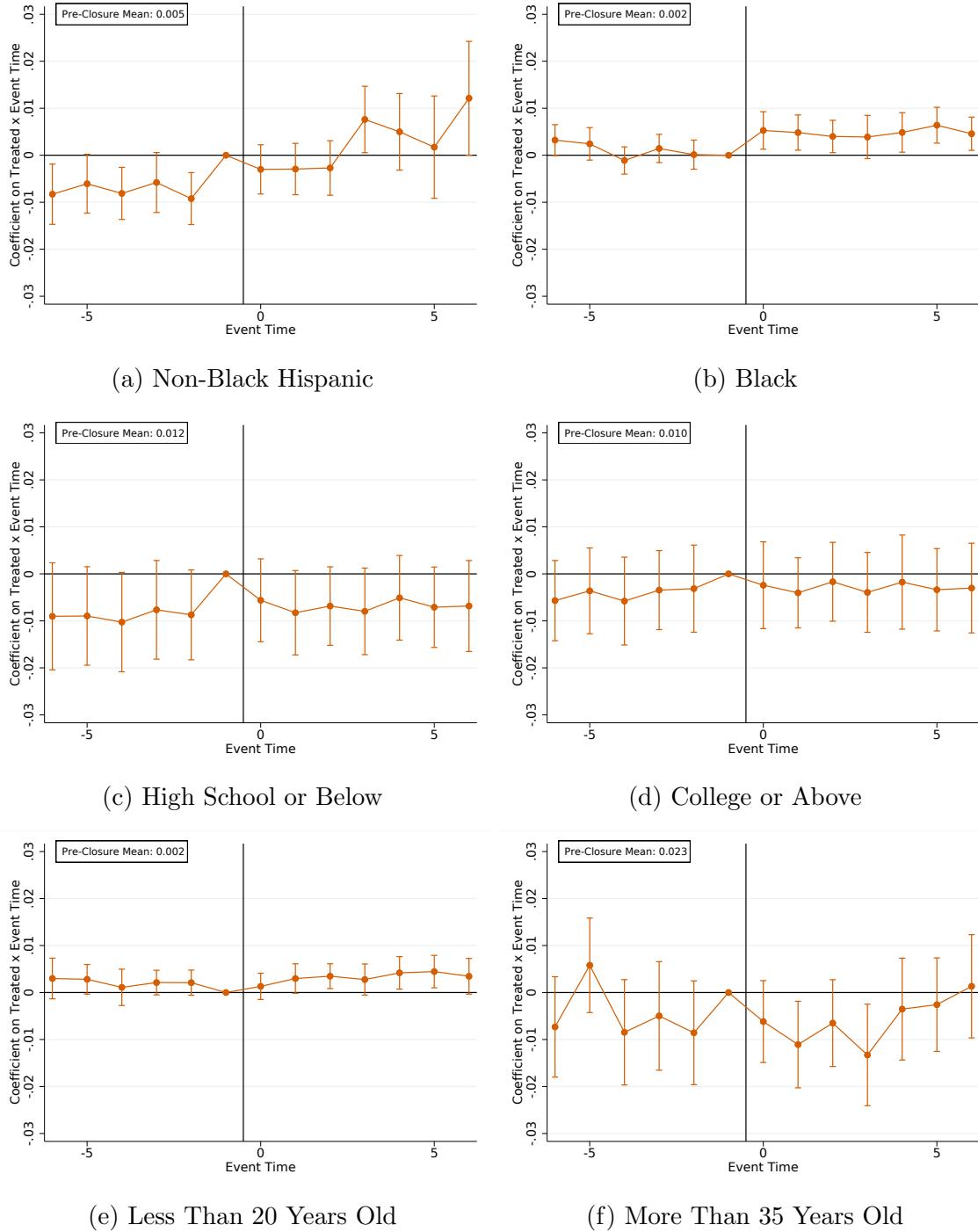
*Note:* In Panels (a) - (d), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable in Panel (a) is the share of births occurring outside of a hospital, in Panel (b) is the share of pregnancies with one or fewer prenatal visits, in Panel (c) is the share of births induced, and in Panel (d) is the share of deliveries that occur via a Cesarean. The sample consists of “receiving counties” as described in the text. Observations are at the county-event time level and are clustered at the county level.

Figure A21: Estimated Impact of Closure on Out-of-County Birth by Subgroup



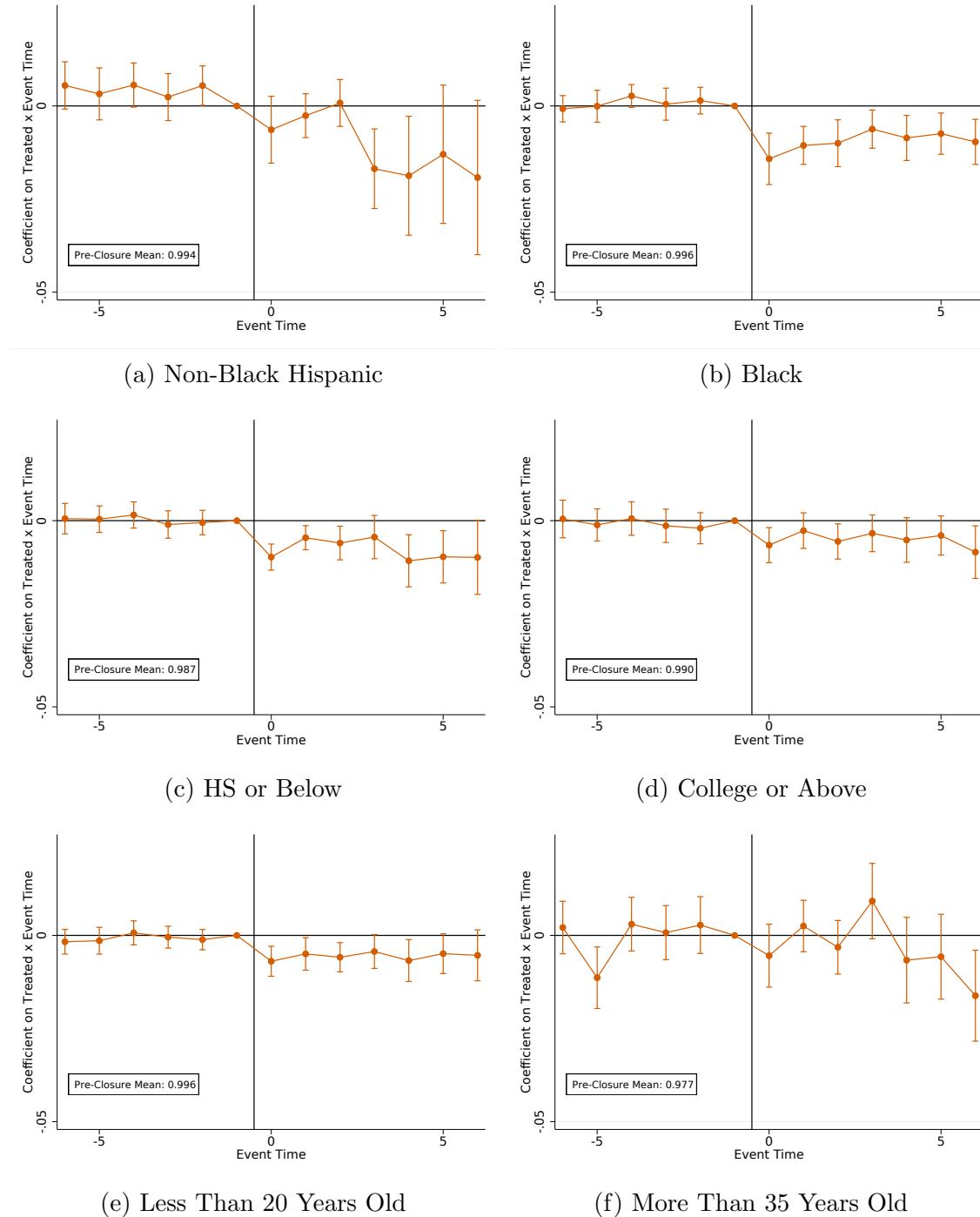
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treatment-control difference from estimating equation (1). The dependent variable is the share of births occurring out of county. Each Panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A22: Estimated Impact of Closure on Out-of-Hospital Birth by Subgroup



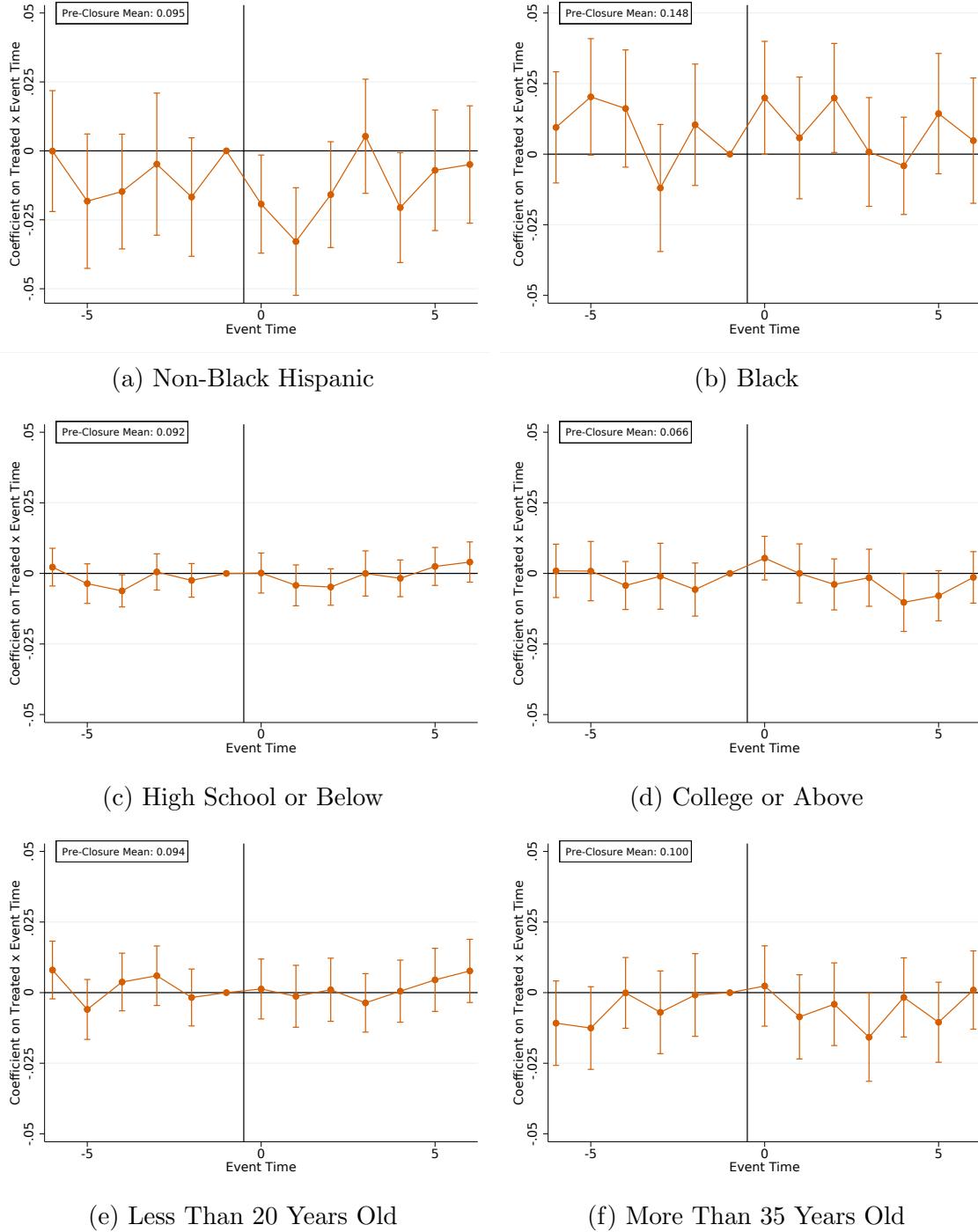
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the share of births occurring out of hospital. Each panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A23: Estimated Impact of Closure on Share of Births in Hospital with Maternity Ward by Subgroup



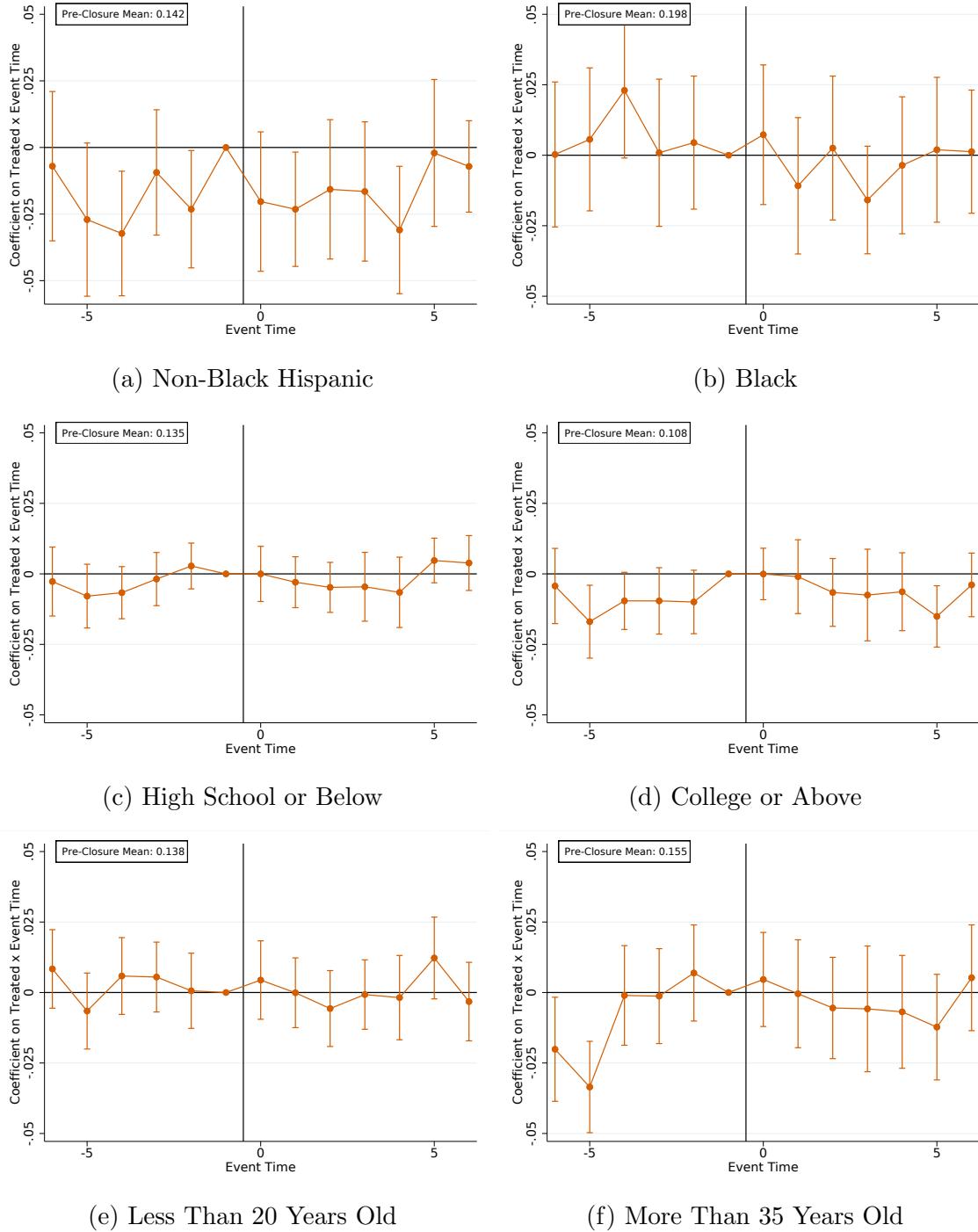
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the share of births occurring in a hospital with a maternity ward. Each Panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A24: Estimated Impact of Closure on Share of Births Low Birth Weight by Subgroup



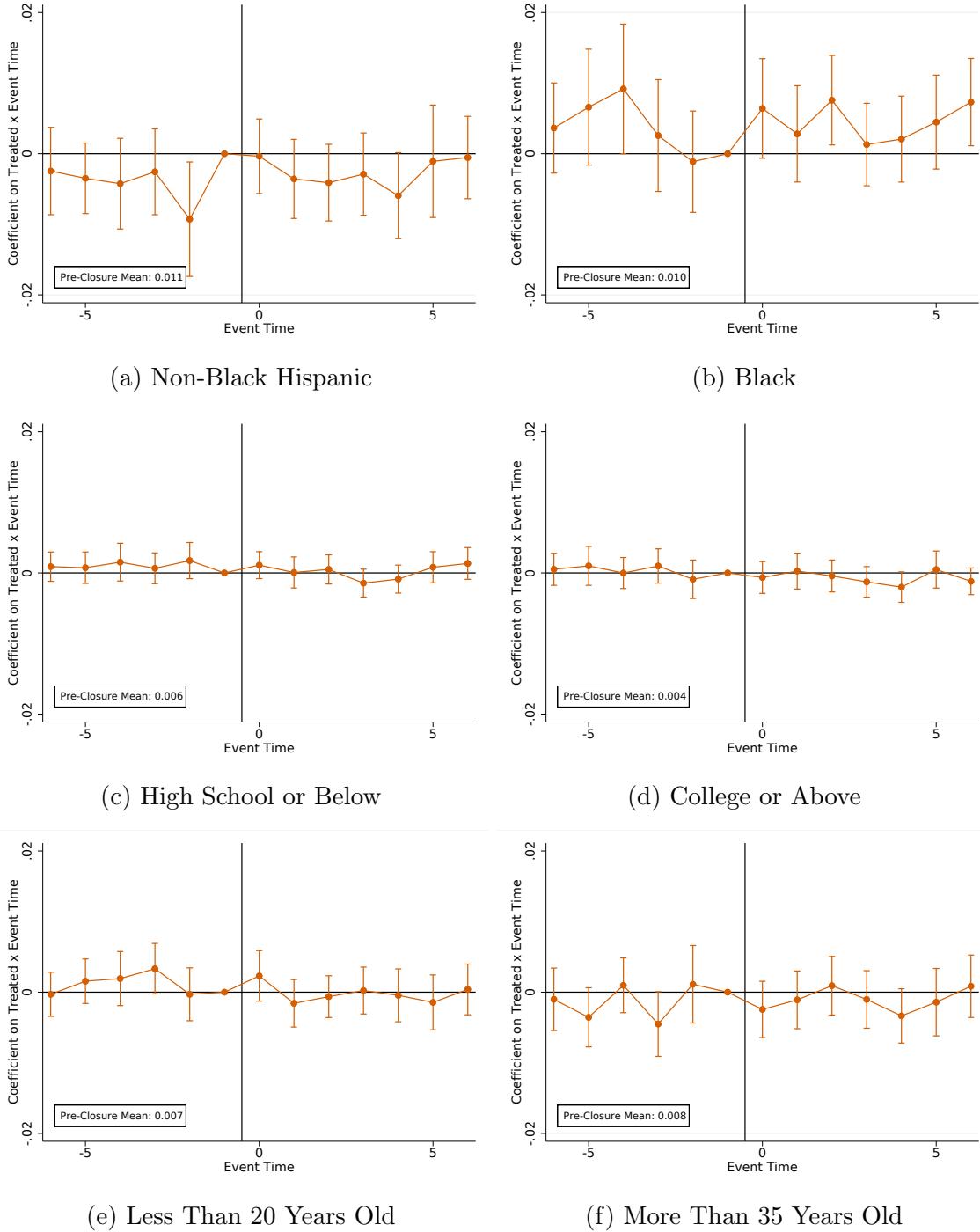
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the share of births low birth weight. Each Panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A25: Estimated Impact of Closure on Share of Births Preterm by Subgroup



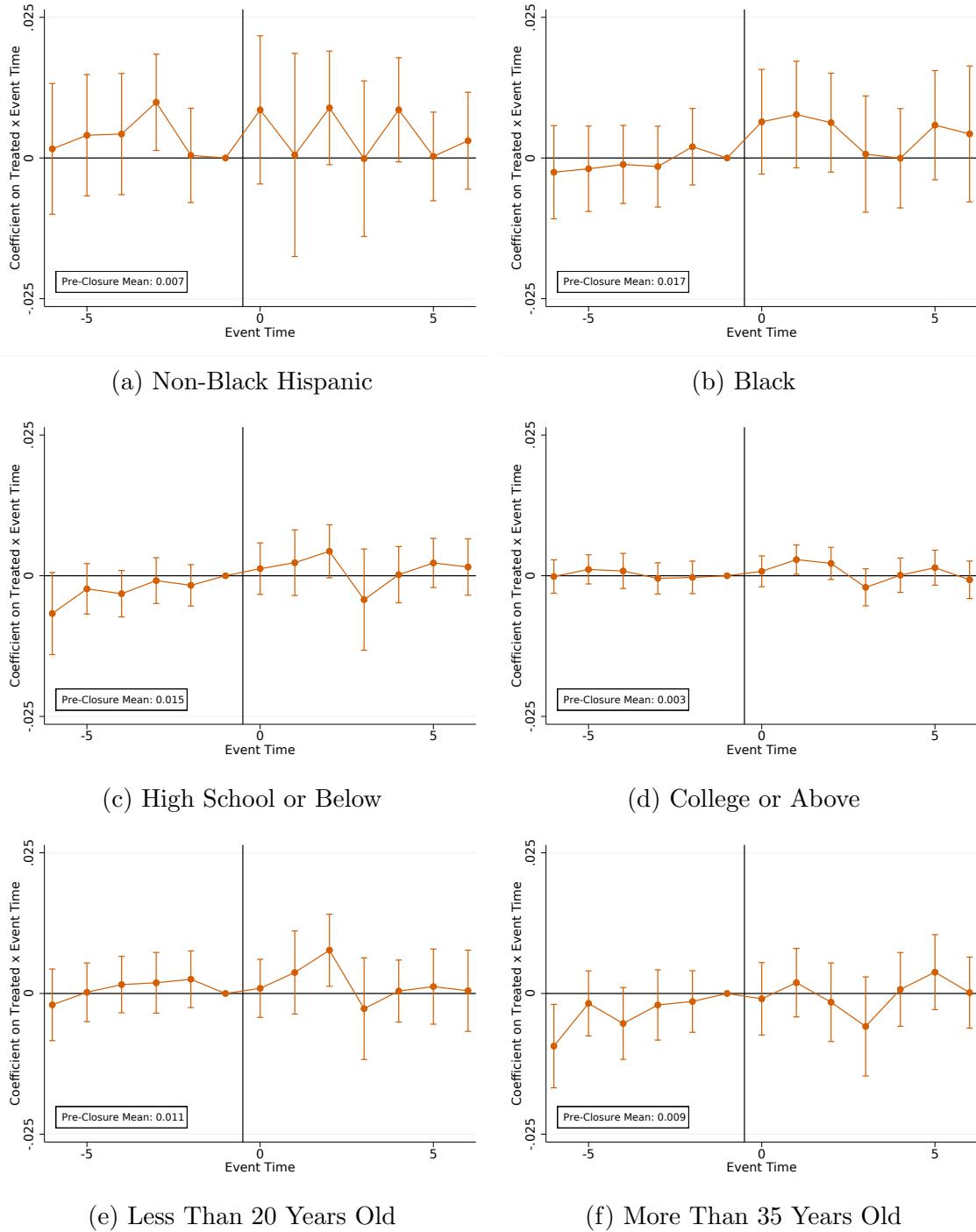
Note: In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the share of births preterm. Each Panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A26: Estimated Impact of Closure on Infant Mortality Rate by Subgroup



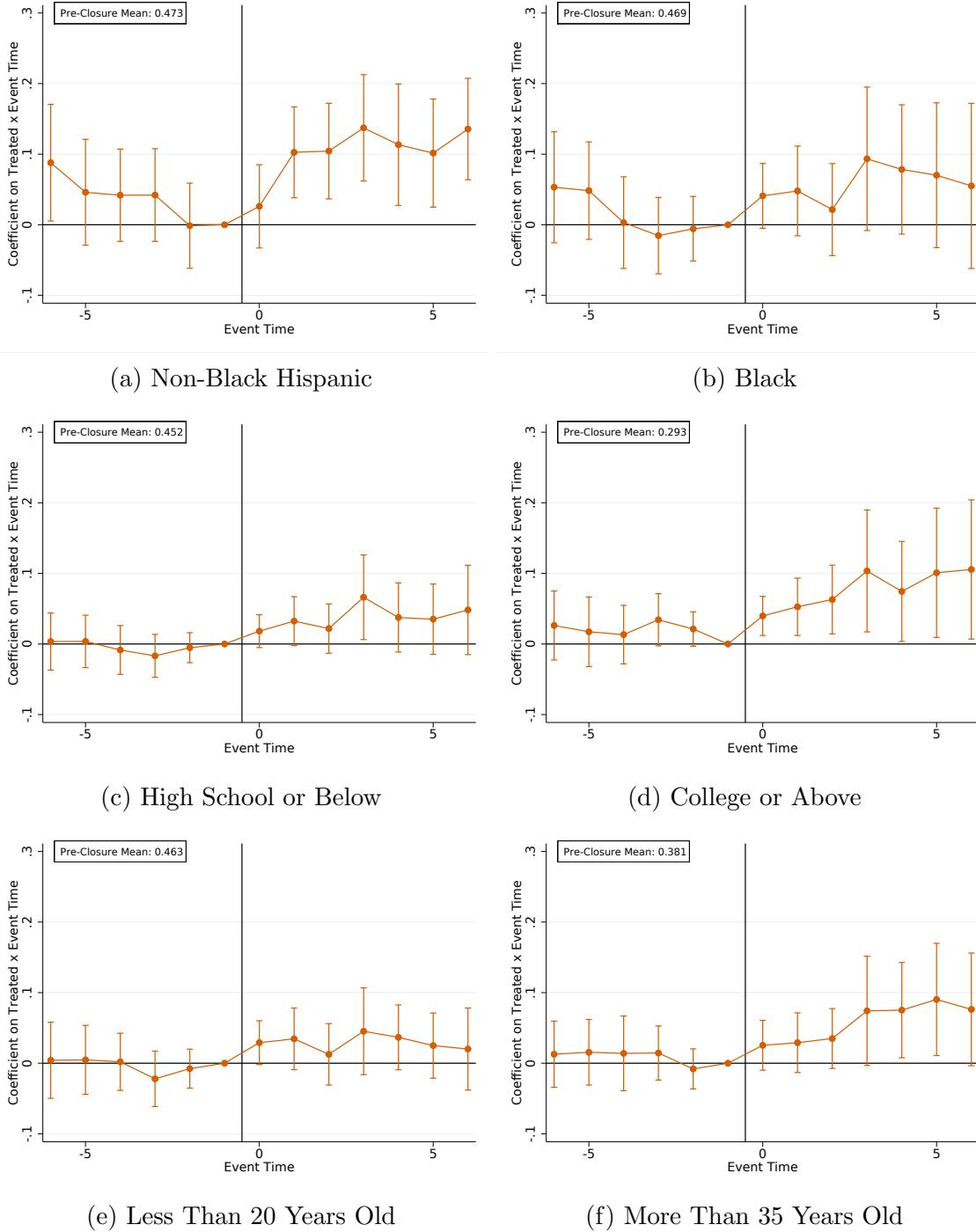
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the infant mortality rate. Each panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A27: Estimated Impact of Closure on Pregnancies with 1 or Fewer Prenatal Visits by Subgroup



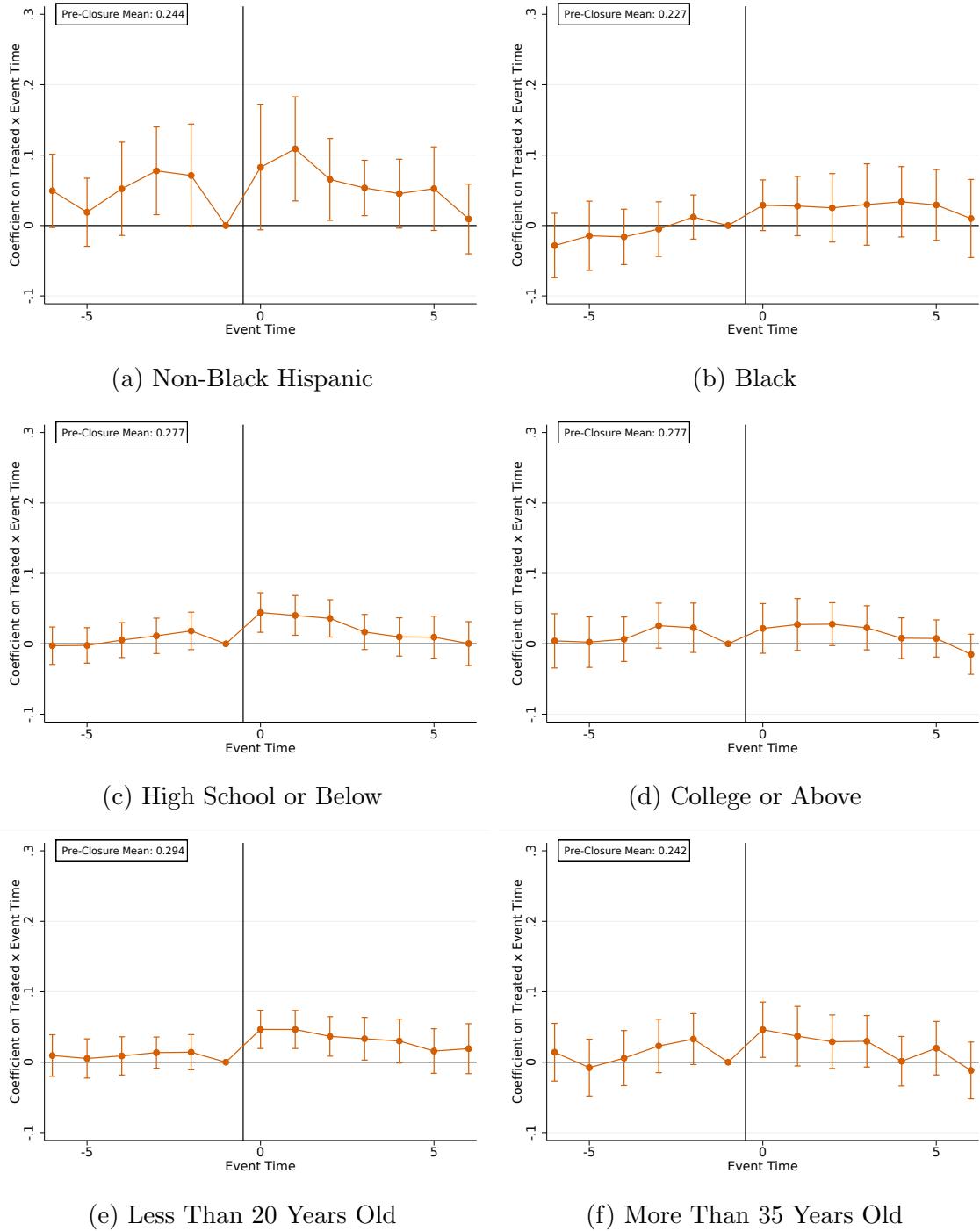
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treatment-control difference from estimating equation (1). The dependent variable is the share of pregnancies with 1 or fewer prenatal visits. Each panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A28: Estimated Impact of Closure on Pregnancies with Low ( $\leq 10$ ) Prenatal Visits by Subgroup



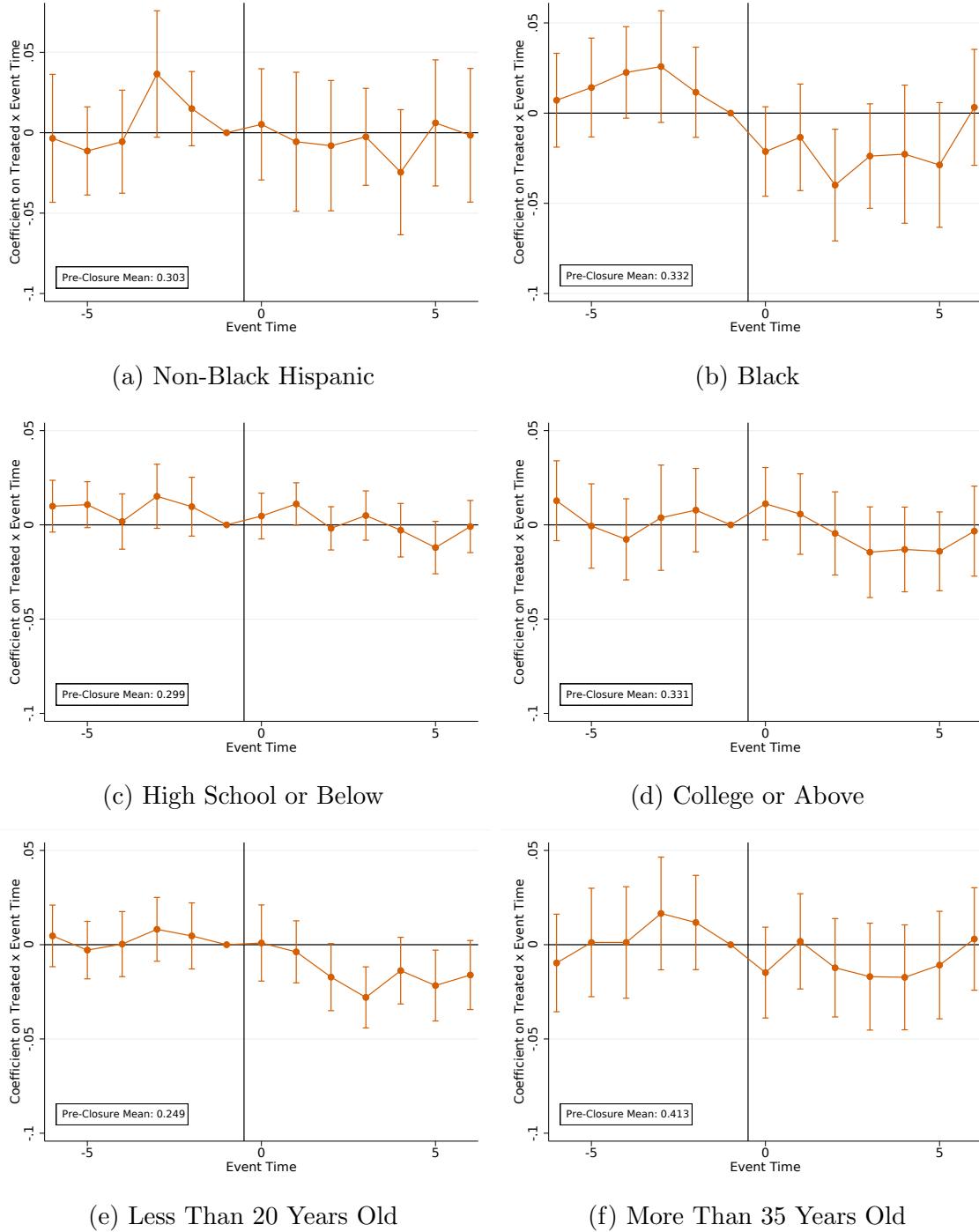
*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treatment-control difference from estimating equation (1). The dependent variable is the share of pregnancies with low ( $\leq 10$ ) prenatal visits. Each panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Figure A29: Estimated Impact of Closure on Share of Births Induced by Subgroup



*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the share of births induced. Each Panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level

Figure A30: Estimated Impact of Closure on Cesarean Rate by Subgroup



*Note:* In Panels (a) - (f), each point, and the associated 95 percent confidence interval, represents the treat-control difference from estimating equation (1). The dependent variable is the share of births delivered via Cesarean. Each panel is estimated on the sample of birth certificates from each county meeting the demographic characteristic listed. Observations are at the county-event time level and are clustered at the county level.

Table A1: Summary Statistics by Hospital Category

	(1)	(2)
	Rural Closures	Rural Non-Closures
Bed Size	57.08 (44.57)	111.00 (110.75)
Number of Births	108.59 (119.87)	523.64 (642.68)
Has Neonatal ICU	0.00 (0.00)	0.03 (0.17)
N	166	1091

*Note:* This table compares characteristics of hospitals in the sample. Column 1 displays characteristics of hospitals that were the sole provider of maternity care in their county in 2002 and close by 2012. Column 2 displays characteristics of hospitals that were the sole provider of maternity care in their county in 2002 and are still open in 2012. Hospital characteristics and provision of maternity care services are based on a hospital's self-report from the American Hospital Association's Annual Survey.

Table A2: Summary Statistics of Matched Treatment and Control Counties

	(1)	(2)
	Treated	Control
Population	23,562 (20,104)	33,297 (104,171)
% Female 18-44	19.9 (1.9)	20.1 (2.0)
% Black	7.8 (14.9)	9.0 (15.0)
% College	19.4 (5.8)	18.9 (4.9)
Unemployment Rate	5.9 (2.6)	6.5 (3.4)
Number of Establishments	507 (398)	628 (1,146)
Per Capita Income	17,900 (2,231)	17,743 (2,284)
Per Capita Transfers	3,532 (629)	3,570 (649)
N	146	146

*Note:* This table reports descriptive statistics of counties that experience a complete loss in maternity care services (treated counties) and their matched control counties. Counties are matched using propensity score matching as described in the text. Summary statistics are computed based on characteristics of the county in 1995.