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Abstract

We examine the impact of public hospitals openings in Mexico on maternal and infant mortality. Using administrative data from the period 2001 to 2019 and taking advantage of the variation in the timing of the opening of public hospitals across Mexican municipalities, we estimate a staggered difference-in-differences model using the Callaway and Sant'Anna (2021) estimator. In doing so, we compare municipalities where a public hospital started to operate against municipalities without a hospital in operation, before and after the opening. Preliminary results show that openings substantially reduced maternal mortality rate (24 maternal deaths per 100,000 births, which amounts to a 40% decrease) and infant mortality rate (192 infant deaths per 100,000 births, which amounts to a 14% decrease). We provide evidence that the decrease in maternal and infant mortality is driven by an increase in institutional deliveries. In addition, we show heterogeneity by the type of hospital and the existence of previous medical infrastructure. In particular, the effect is driven by the opening of level II hospitals, and the opening of the first hospital in a municipality. This research closes a gap in our understanding of the health effects of expanding healthcare infrastructure in the developing world.

JEL Codes: I15, H43.

Keywords: Impact of hospitals, infant mortality, maternal mortality, hospital closures, institutional delivery

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1 Introduction

Despite significant progress, maternal and infant mortality continues to be a pervasive issue in middle income countries. In 2020, the maternal mortality rate in in low-middle income countries was 253 (per 100,000 live births) compared to 12 in high-income settings, while infant mortality in 2021 was 33 (per 100,000 live births) in the former group compared to 4 in the latter group.[2] A large share of this mortality is preventable. The main determinants of maternal mortality are direct obstetric complications, such as postpartum hemorrhage, pre-eclampsia, and infection, most of these preventable by providing access to adequate technologies and services. For example, there is a positive correlation between maternal mortality and having to travel long distances to obtain medical care (see Souza et al. 2024). The leading causes for neonatal deaths are related to premature birth, birth complications, neonatal infections and congenital anomalies, with lack of access to quality health services being one of the key determinants (WHO, 2024).

Existing evidence, mostly from high-income settings, suggests that access to hospitals can reduce maternal and neonatal mortality, especially if the hospital is specialized or advanced and if it provides high-quality obstetric care. Geographical proximity to hospitals is associated with lower risks of adverse maternal outcomes and reduced neonatal intensive care unit (NICU) admissions (Minion et al., 2022). Conversely, losing access to hospital-based obstetric care, particularly in rural areas, is associated with higher rates of out-of-hospital births, preterm births, and deliveries in hospitals without obstetric units (Kozhimannil et al., 2018), as well as worsened prenatal, infant and delivery outcomes (Durrance et al., 2024). The hospital type and quality of care provided are also associated with outcomes. The volume of births is associated with better survival rates among high-risk infants, largely due to the presence of advanced neonatal intensive care units, specialized infrastructure, and experienced medical staff (Walther et al., 2020; 2021; Daysal et al., 2015). Higher quality of hospital care is also associated with better outcomes, such as improved patient safety and reduced infant mortality (Aguilera & Marrufo, 2007).

However, while improving access to hospitals is a key policy recommendation and response to high maternal and neonatal mortality in many middle-income countries, to our knowledge, there is no causal evidence of the effect of hospital infrastructure in these settings.

We estimate the impact of the gradual opening of public hospitals by the Mexican Ministry of Health (*Secretaría de Salud*, SSA) between 2001 and 2019. During this period, the number of SSA hospitals in Mexico increased from 332 to 722, and the number of municipalities with at least one SSA hospital increased from 259 to 503. The SSA hospital was often the first in the municipality and provides free services for the population without access to formal employment-related health insurance. We use a staggered difference-in-difference design with municipal level administrative data on the opening of hospitals, institutional deliveries, and maternal and neonatal deaths. Our findings indicate that hospital openings substantially reduced maternal mortality rate (24 maternal deaths per 100,000 births, which amounts to a 40% decrease).

Our analysis offers three contributions. First, we provide rigorous causal evidence on the effect of hospital openings, a primary health policy in many middle-income countries. Prior evidence is mostly correlational and from high-income settings. Second, we contrast the effects of the first hospital opening (extensive margin) and subsequent openings and examine

[2] World Bank Gender Data Portal. Accessed May 14th, 2024.

heterogeneity by hospital type. Our finding that the first opening – particularly of level II hospitals – has larger impacts can help prioritize investments in health infrastructure. Third, we identify increased institutional deliveries as a potential channel for the impact.

2 Background of Mexican Health Care System

The Mexican health care system is composed by 3 main organizations:[3] The *Secretaría de salud* (SESA), the *Instituto Mexicano del Seguro Social* (IMSS), and the *Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado* (ISSSTE). The focus of this study is the opening of SESA hospitals, a public institution that provides services to individuals without social insurance. IMSS provides services to individuals with a job in the formal sector and ISSSTE provides services to employees of the federal government. In addition, individuals can also attend private hospitals.[4]

In our sample, most births take place in SESA, IMSS, ISSSTE and private hospitals.

3 Data

Our empirical analyses rely on data from several sources.

Treatment variable

We use administrative data from the Mexican Ministry of Health that lists the hospitals in operation for every given year (CLUES dataset) to identify hospitals openings in our time period. Using these data, we identify the municipalities with a hospital opening and create an indicator variable taking the value of 1 from the year in which the first hospital in the municipality opened. For municipalities where there were hospitals in operation prior to 2001, the indicator variable has the value of 1 for our entire study period.

Outcomes of interest

We constructed two different municipal-level panel data sets that cover the period 2011 to 2019.[1] First, we use administrative mortality records from the National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*, INEGI). This dataset provides individual level information about maternal deaths in the country. Importantly, this dataset identifies the cause of death, allowing us to identify maternal deaths, as well as the place or residence of the deceased. Finally, this dataset allows us to observe the age of the deceased, allowing us to identify infant deaths. Since our treatment variable is at the municipal level, we aggregate the mortality data at the municipal-year level. Using these data we construct a measure of maternal mortality rate as the total number of maternal deaths over the total number of live births multiplied by 100,000.[2]

Second, we use individual-level birth certificates from INEGI. This data allow us to identify institutional births, as well as child and mother characteristics.

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[3] For a detailed description of the Mexican health system, see Gómez Dantés, et al. (2011).

[4] There are some other organizations with their own hospitals, such as the military and the state-owned petroleum company (PEMEX by its Spanish acronym).

Table 2 summarizes these three different types of data sources: Birth administrative records, Maternal Health administrative records, and Hospital data.

Table 1 – Data sources

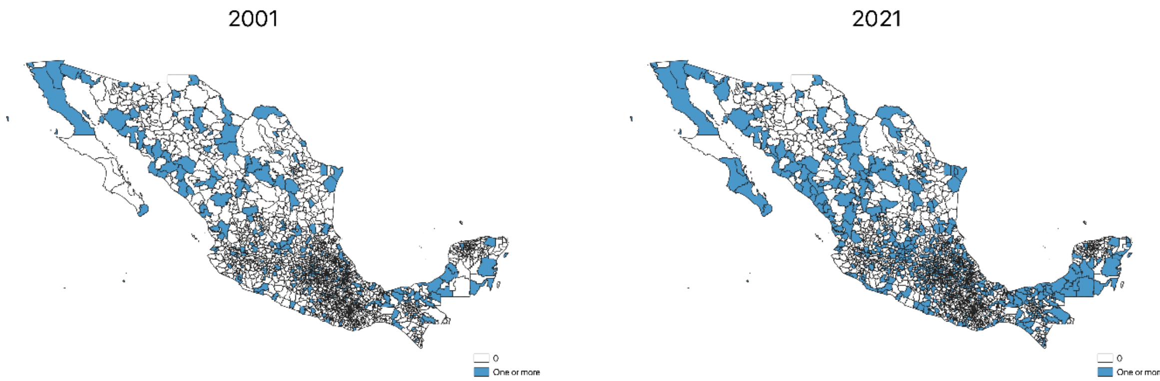
Birth administrative records	Maternal Health administrative records	Hospital data
• Individual level data • Geographic information (municipality of habitual residence, municipality of birth) – key to identify areas exposed to treatment • Parents' personal info (age, education, marriage status) • Place of birth and person that delivered the birth– key to identify institutional births	• Individual level data • Geographic information • Maternal deaths classified by the Ministry of Health, including cause of death • Personal information (age, employment, education, Health insurance status, etc.)	• SSA active hospitals annual records since 2001 + information from other health systems from CLUES data set (ISSSTE, private). Limited info on IMSS hospitals. • Alternatively, we used birth data since 2008 to identify the year each hospital (of any system) started making deliveries

Table 2 - Summary Statistics, 2001 and 2019

Variable	2001	2019
Number of SESA hospitals	332	722
Municipalities with SESA hospital	259	503
% Institutional births	50%	78%
Infants deaths (per 100K births)	1,250	1,116
Maternal deaths (per 100K births)	50	41.4

Figure 1 shows the change between 2001 and 2021 on the geographic location of Mexican municipalities that have at least one SSA hospital (marked in blue).

Figure 1 – SESA Hospital presence in Mexican municipalities, 2001 and 2021



4 Estimation Strategy

We use a staggered difference-in-differences (DiD) approach to estimate the effect of hospital openings on maternal and infant health by comparing maternal and infant mortality in municipalities where a public hospital started to operate against municipalities without a hospital in operation, before and after the opening (Callaway and Sant'Anna 2021).

We implement this estimator using the *csdid* package in Stata, which estimates group-time average treatment effects over the period of analysis using an event study specification (in our case municipality-year during the 2001-2019 period).[5] The group-time average treatment effect on the treated are calculated, using the event study coefficients, as follows:

$$ATT_{(z,t)} = \mathrm{E}[y_t(z) - y_t(0) | Z_z = 1]$$

where, z, t correspond to municipality and year, respectively. This parameter estimates the average causal effect of hospital openings on maternal mortality rates between 2001 and 2019. We use the inverse probability weighting estimator and only never treated observations in the control group.

The identification assumption is that municipalities with no hospitals in operation must be a good counterfactual for municipalities where a hospital opened. This implies that there should not be differential trends between treated and untreated municipalities. We test the plausibility of this parallel-trends assumption in the next section.

5 Main Results and Robustness Tests

Table 3 below shows that opening a hospital in a municipality substantially reduce maternal mortality rate in that municipality (24 maternal deaths per 100,000 births, which amounts to a 40% decrease), and infant mortality rates (192 infant deaths per 100,000 births, which amounts to a 14% decrease).

[5] Rios-Avila et al (2023).

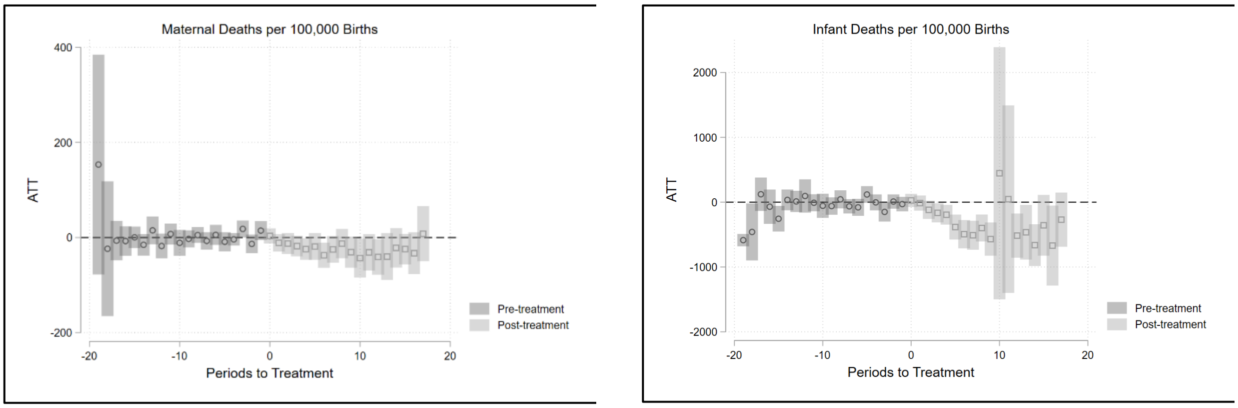
Table 3. The effect of Hospital Openings on Maternal and infant Mortality

	(1)	(2)
Variables	Maternal Deaths per 100,000 Births	Infant Deaths per 100,00 Births
Hospital Opening	-24.188**	-192.206***
	(12.174)	(89.305)
N	40,188	40,188
Pre-treatment mean	60.908	1,365.081

Note. Estimates obtained using the doubly robust estimator from CS, and only never treated observations in the control group. Heteroskedasticity-robust standard errors clustered at the municipality level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

As mentioned before, an essential question when estimating a DiD design, is the plausibility of the parallel trends assumption to hold. To assess this assumption, we perform an event study analysis. Figure 3 below presents the coefficients from the analysis. As can be seen, prior to the opening of the hospitals there is no statistically significant difference between municipalities with and without a hospital opening in terms of maternal mortality or infant mortality. After the opening, however, there is a statistically significant decrease in maternal and infant mortality in municipalities with a hospital opening in comparison to municipalities with no hospital in operation.

Figure 2. Event Study for Maternal Mortality Rate (left) and Infant Mortality Rate (right).



Notes. Estimates obtained using the IPW estimator from CS, and only never treated observations in the control group.

In addition to the parallel-trends assumption test, we analyzed the robustness of our result to i) using an alternative dataset to construct the opening date of the hospitals, ii) the adoption of Seguro Popular, iii) the possibility that our results arise only by chance, and iv) an alternative estimation method.

With respect to the alternative dataset to construct the opening date of the hospitals, we use birth data from the Mexican Ministry of Health providing the hospital in which the birth took place.[6] A drawback of this dataset, however, is that data is only available starting in 2008. Using this data, we identify a hospital opening when births start to be registered in that hospital. Results from this alternative opening data are consistent with the baseline estimates (see table A.1).

With respect to the role of Seguro Popular. We extend our baseline models by including a control variable that measures the adoption of Seguro Popular at the municipality level divided by the total population in the municipality. Results are robust to the inclusion of this control variable (see table A.2).

To discard the possibility that our results arise only by chance, we perform a permutation test. In this test, we re-estimate our baseline models 500 times using placebo hospital opening dates to derive the distribution of the coefficients from the placebo treatments. The null hypothesis of this test is that there is no effect of the program. Results showed that our coefficients lie on the far-left tail of the distribution, allowing us to reject the null hypothesis.

Finally, we explore the robustness of our results to alternative estimators. Table 4 below presents the results of estimating our baseline model using the Synthetic Difference in Difference (SDID) model.[7] As can be seen, the coefficient is robust to the change of the estimation method.

[6] Birthplace data is not available from the INEGI birth data.
[7] Arkhangelsky et al. (2021), implemented in Stata by Clarke et al (2023).

Table 4. The effect of Hospital Openings on Maternal Mortality. Alternative Estimator (SDID)

	(1)	(2)	(3)	(4)
Variables	Maternal Deaths per 100,000 Births		Infant Deaths per 100,00 Births	
Hospital Opening SSA	-24.188**	-8.873*	-192.206***	-224.00***
	(12.174)	(4.528)	(89.305)	(53.761)

Note. Estimates obtained using the doubly robust estimator from CS, and only never treated observations in the control group. Heteroskedasticity-robust standard errors clustered at the municipality level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

6 Potential Mechanisms

In this section we explore potential mechanisms driving the decrease in maternal and infant health due to hospital openings.

First, we analyze the effect of hospital openings on institutional births. Hospital openings could decrease maternal mortality by increasing access to institutionalized births. Table 5 below shows the results. As can be seen, hospital openings substantially increase institutional births. In particular, opening a hospital increases the share of institutional births in 6.7 percentage points.

Figure 3 presents the event study plot for institutional deliveries. As can be seen, before the opening of a hospital, treated and untreated municipalities had no difference in institutional births, providing support for the identification strategy.

Second, we explore if the type of hospital matters. In particular, we re-estimate our DiD model first using only level two hospitals (hospitals where births take place) and second using only level three hospitals (specialty hospitals). Figures 4 and 5 present the event study plots for these new models. As can be seen, the main effect is driven by the level two hospitals.

Third, we analyze if the number of hospitals opened matters. In other words, is it the opening of the first hospital or the opening of subsequent ones. Figure 6 shows the event study plots of estimating the model for the opening of the second hospital. As can be seen, there is no effect of the opening of a second hospital.

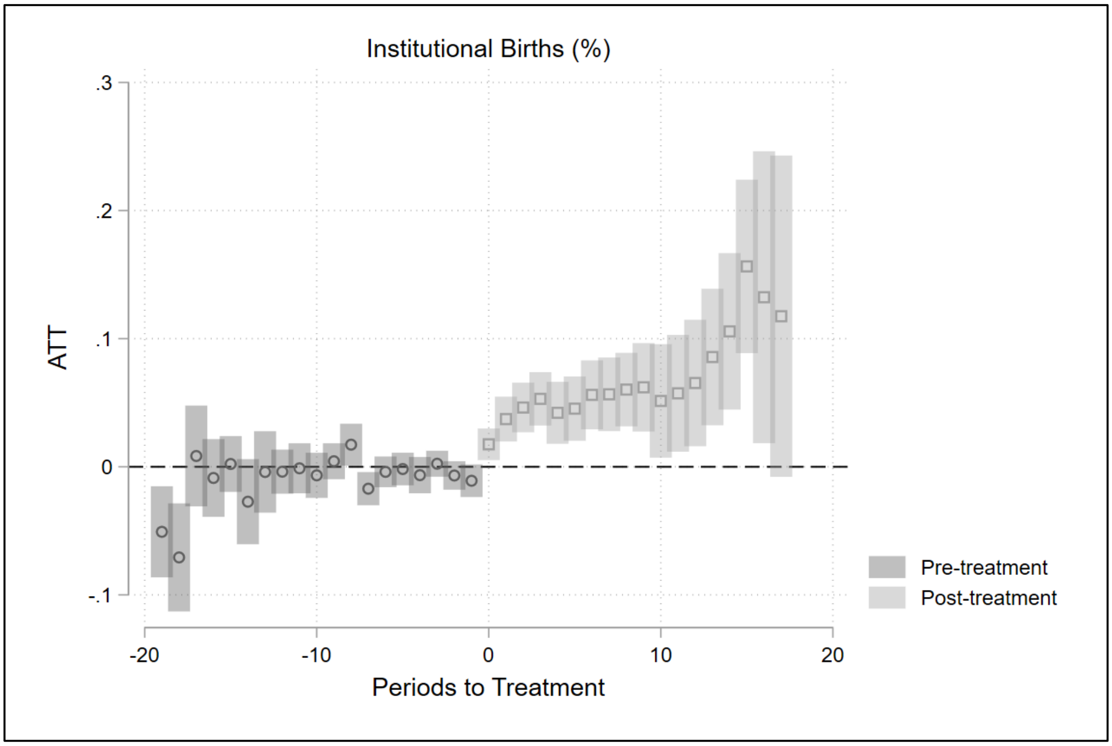
Previous results suggest that it is not only about the infrastructure, but the increase in access that comes from the opening of a hospital in a place where there was no hospital that could treat births.

Table 5. The effect of Hospital Openings on Institutional Deliveries

	(1)
Variables	Institutional Deliveries
Hospital Opening	0.067***
	(0.013)
N	40,188
Pre-treatment mean	0.664

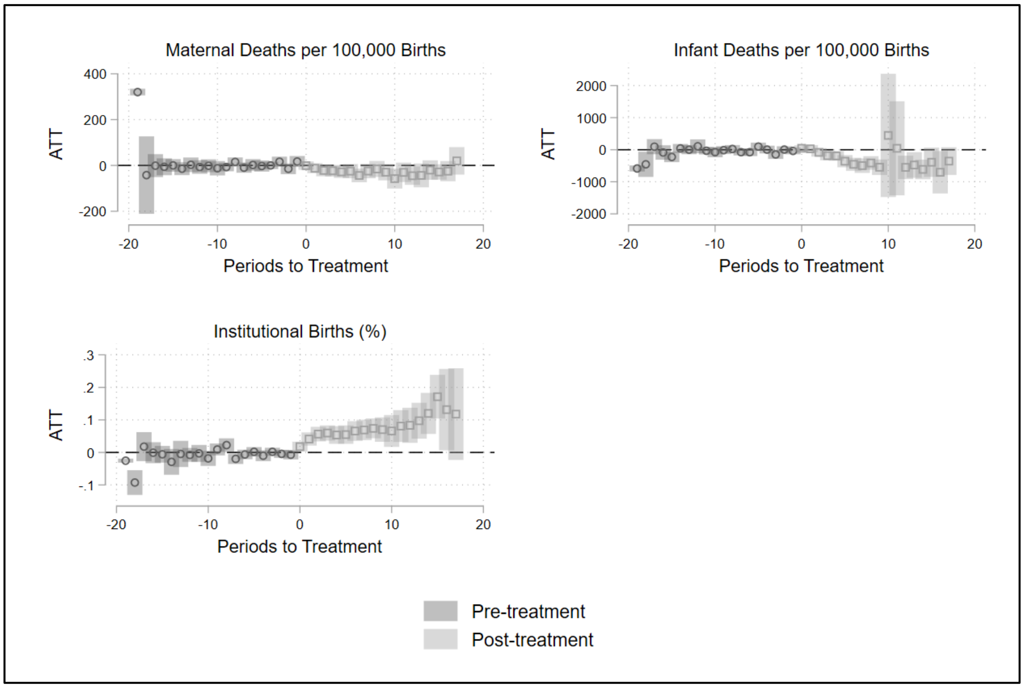
Note. Estimates obtained using the doubly robust estimator from CS, and only never treated observations in the control group. Heteroskedasticity-robust standard errors clustered at the municipality level are reported in parentheses.*** p<0.01, ** p<0.05, * p<0.1

Figure 3. Event Study for Institutional Deliveries.



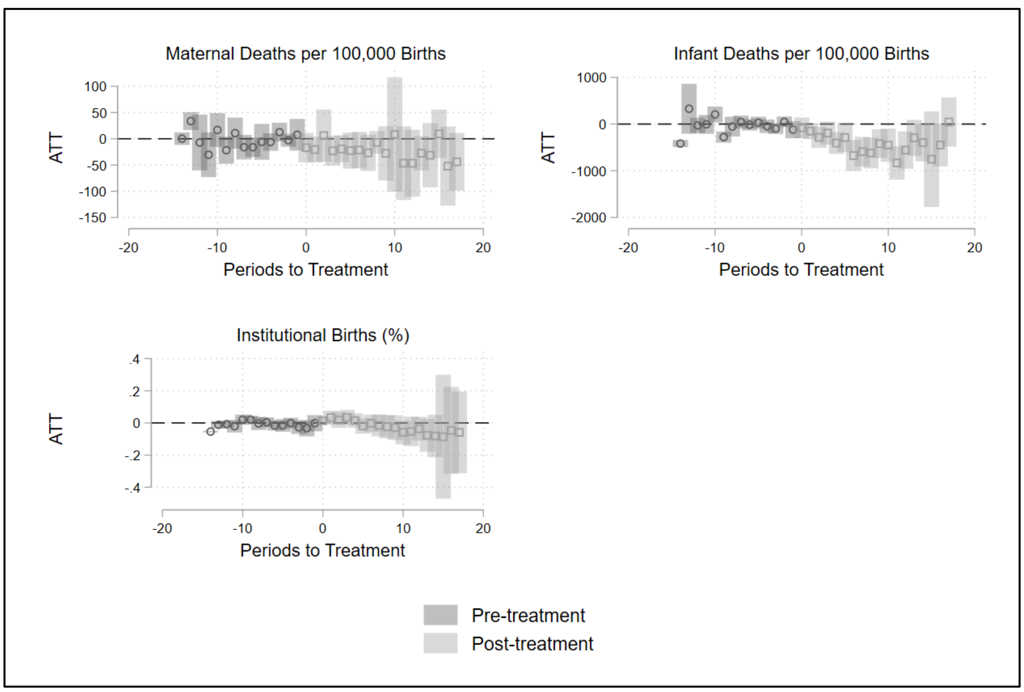
Notes. Estimates obtained using the IPW estimator from CS, and only never treated observations in the control group.

Figure 4. Event Study for the Opening of Level 2 Hospitals.



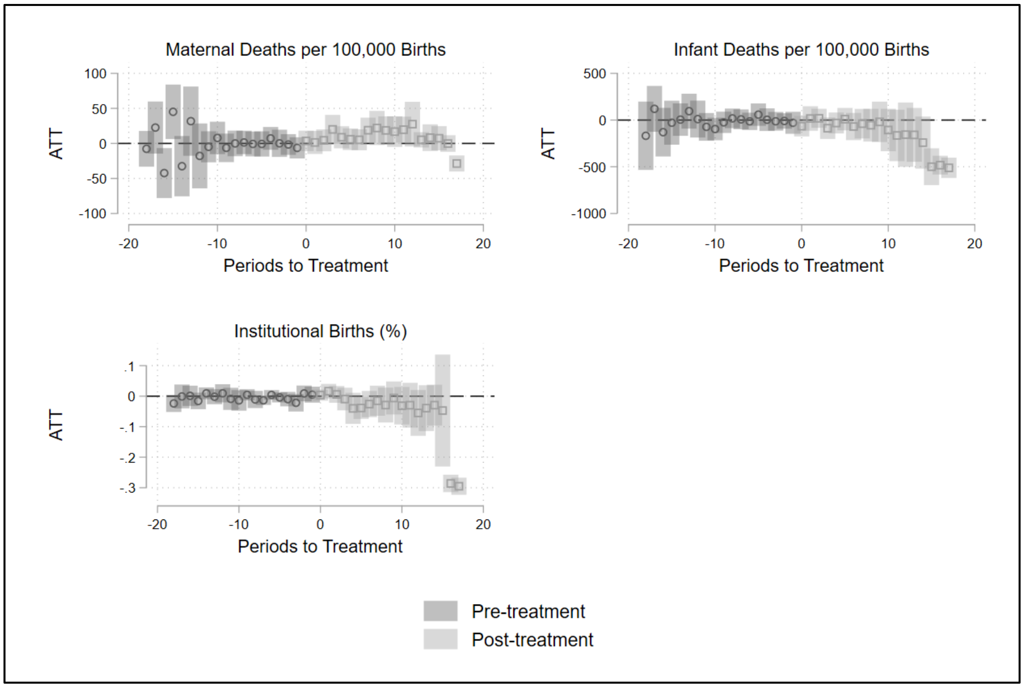
Note: Estimates obtained using the IPW estimator from CS, and only never treated observations in the control group.

Figure 5. Event Study for the Opening of Level 3 Hospitals.



Note: Estimates obtained using the IPW estimator from CS, and only never treated observations in the control group.

Figure 6. Event Study for the Opening of the Second Hospital.



Notes. Estimates obtained using the IPW estimator from CS, and only never treated observations in the control group.

7 Discussion and Conclusion

We study whether the opening the first public hospital on a Mexican municipality improves three important birth outcomes: maternal, infant deaths and institutional deliveries. Results show that the introduction of this new infrastructure is accompanied by a reduction in maternal mortality and infant mortality and an increase in institutional deliveries. The results are both statistically and economically significant: On average, a reduction of 24.2 maternal births (from a baseline mean of 60.9); a reduction of 192 infant deaths (from a baseline mean of 1,365.1); and an increase in 6.7 percentage points in the probability of a birth occurring in a hospital (from a baseline mean of 66.4%).

The pre-intervention analysis shows that, prior to the opening of the hospitals, there is no statistically significant difference between municipalities with and without a hospital opening in terms of maternal mortality, infant mortality, or institutional deliveries. Also, results are robust to changes in the source data set, the estimation method, by controlling for the introduction of the Seguro Popular and by performing a permutation test. All this reinforces the causal interpretation of our results; the observed effects are the result of the introduction of the new public hospital.

The simultaneous effect of both the institutional deliveries and the infant and maternal mortality rates seem to suggest that, as expected, the protective effect of hospitals is related to the fact that births occur more frequently in an institutional setting, where more resources are available to deal with life-threatening complications arising during childbirth. This interpretation is reinforced when taking into consideration the type of hospital that is being introduced; most of the effect seems to come from the introduction of level-2 hospitals (usually prepared to tend births), rather than level-3 specialty hospitals.

Finally, results tend to disappear when looking at the effects of the second public hospital opening in a given municipality, which reinforces the idea that the effect occurs by the increased access to a hospital that the first opening provides.

Our results are generally consistent with the previous literature (for developed countries) relating distance to hospitals or institutional deliveries with better birth outcomes.

8 References

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Appendix A

Table A.1. The effect of Hospital Openings on Maternal and Infant Health. Using birth data to identify hospital openings

	(1)	(2)	(3)	(4)
Variables	Maternal Deaths per 100,000 Births		Infant Deaths per 100,00 Births	
Hospital Opening SSA	-23.025	-14.125	-305.657***	-329.906***
	(17.063)	(12.393)	(70.542)	(67.604)
Alternative treatment		X		X
N	24,344	23,723	24,344	23,723

Note. Estimates obtained using the doubly robust estimator from CS, and only never treated observations in the control group. Heteroskedasticity-robust standard errors clustered at the municipality level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A.2. The effect of Hospital Openings on Maternal and Infant Health.

Controlling for the Seguro Popular

	(1)	(2)	(3)	(4)
Variables	Maternal Deaths per 100,000 Births		Infant Deaths per 100,00 Births	
Hospital Opening SSA	-24.188**	-25.071**	-192.206***	-209.916**
	(12.174)	(12.265)	(89.305)	(91.351)
Control for Seguro Popular		X		X
N	40,188	40,170	40,188	40,170

Note. Estimates obtained using the doubly robust estimator from CS, and only never treated observations in the control group. Heteroskedasticity-robust standard errors clustered at the municipality level are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1