



**Landmines, Maternal Stress, and Neonatal Health: Evidence
from Colombia's Childbirth Outcomes**

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Abstract

Violence can have lasting effects on individuals, even if exposure occurs during pregnancy. This study examines the impact of violence on newborns in Colombia by leveraging the quasi-random occurrence of landmine explosions. We investigate how the stress caused by exposure to landmines during pregnancy influences neonatal health. By combining the geolocation and timing of landmine explosions with the coordinates of health institutions where deliveries occurred, we present evidence that maternal stress during pregnancy may act as a potential mechanism negatively affecting birth outcomes. Newborns are more likely to have low birth weight when their mothers were exposed to a landmine explosion during the first trimester of pregnancy. Furthermore, exposure to explosions in the third trimester increases the likelihood of premature birth.

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1. Introduction

Organized criminal groups employ various methods of coercion, including extortion, drug trafficking, forced recruitment, and violence, all of which lead to significant adverse consequences for local communities. Women are particularly vulnerable in conflict situations, occupying various roles within society. In addition to experiencing the same physical violence as men, women often bear the additional burden of ensuring their families' survival while facing limited access to medical care and restricted livelihood opportunities. Gender inequality further exacerbates their plight, as women are frequently treated as spoils of war, with sexual violence, including rape, employed as a strategy of terror. Women, predominantly civilians, are disproportionately affected by armed conflict, facing direct threats such as landmines. For pregnant women, the consequences extend to their unborn children, as the psychological and physical stress they endure during pregnancy affects fetal development. This paper seeks to examine the effects of fear induced by violence on children's health, specifically birth outcomes, with stress acting as a suggestive mechanism. The focus of this paper is on how conflict in Colombia influences maternal and neonatal health.

Anti-personnel landmines are deployed by armed groups as a tactic to control territory and harm the civilian population. While these mines are strategically placed, the timing of their detonation and the number of pregnancies affected remain unpredictable. Using administrative data on vital statistics and geo-referenced health centers, combined with information on landmine incidents, we investigate the mechanisms through which violence impacts birth outcomes. By comparing birth outcomes of children born to mothers exposed to landmine explosions during pregnancy with those of mothers who gave birth in the same hospitals but were not exposed, we can isolate the effects of these explosions on birth characteristics. This analysis sheds light on how the use of landmines during conflict affects pregnant women and disrupts fetal development.

We concentrate on Colombia, which is the only country in the Americas where armed groups use anti-personnel landmines, even though these devices are prohibited by International Humanitarian Law and the Ottawa Convention. Until 2016, Colombia was the second country in the world with the highest number of victims of landmines ([ABColumbia, 2021](#)). Our analysis period covers from 2002 to 2017, and in fact, between 2002 and 2010 was the period when most Colombians were affected by landmines. Of the civilian victims, almost 30% are children ([Romero and Garcia, 2017](#)). However, this statistic does not consider the children affected during their prenatal development.

To examine the effects of landmine explosions on birth outcomes, we use administrative data that geo-references the locations of these incidents. We compare birth outcomes by assessing whether the mother gave birth in a healthcare facility located within a 15 km radius of a landmine explosion.

We employ a two-way fixed effects panel to compare outcomes based on the trimester of exposure to landmine explosions. Our analysis uses vital statistics, including birth outcomes and information about mothers and the healthcare centers where deliveries occurred. To estimate the trimester of exposure, we rely on the "expected" birthdate rather than the actual birthdate, following the methodologies of [Black et al. \(2016\)](#) and [Currie et al. \(2022\)](#), to avoid bias related to gestational age. The areas analyzed include both municipalities and health providers exposed to landmine explosions at any time during the study period. We linked the georeferenced database of healthcare providers, provided by the Ministry of Health, to the vital statistics records. Exposure to conflict was determined by whether a landmine explosion occurred within a 15 km radius of a healthcare provider, and then we compared the birth outcomes for children born in those hospitals.

First, the stress induced by landmine explosions, particularly its impact on maternal mental health during pregnancy, disrupts cortisol and ACTH levels. The neuroendocrine system acts as a mediating pathway between prenatal psychosocial factors and birth outcomes, influencing both fetal and infant brain development ([Metcalf et al., 2011](#); [Singhal, 2019](#)). Second, the presence of landmines indicates ongoing armed conflict, placing mothers in extremely difficult circumstances. As a result, they often become direct victims of the conflict, suffering both physical and mental health declines due to limited access to healthcare. These adverse conditions are passed on to their unborn children ([Clark et al., 2020](#); [Dustmann and Fasani, 2016](#)). Additionally, prenatal stress can lead to shorter gestational periods and lower birth weights ([Wadhwa et al., 1996, 1993](#)).

The timing of exposure affects mothers differently, which is why our primary analysis is conducted by trimester. Intrauterine growth is particularly restricted by stress during the first trimester, while gestational age is most impacted by heightened maternal psychological distress during mid-pregnancy ([Brown, 2014](#)). The literature shows that a conflict-related death occurring 9 to 6 months before delivery is modestly associated with an increased probability of delivering a baby weighing less than 2,500 grams ([Currie et al., 2024](#); [Mansour and Rees, 2012](#); [Torche and Villarreal, 2014](#)).

Our findings remain robust across varying buffer radii from the healthcare provider. We document that exposure to a landmine explosion increases the likelihood of low birth weight by 2.72% when the mother is affected during the first trimester. Additionally, prematurity increases by 3.92% when the mother is exposed during the third trimester. Notably, being single significantly raises both risks compared to other marital statuses. Furthermore, mothers with only primary education or less are more likely to have a baby with low birth weight if exposed during the third trimester. While no significant differences were observed across maternal age or higher educational levels, we found no significant differences in the likelihood of cesarean sections. However, exposure to an event during the second trimester was associated with an increase in the number of prenatal check-ups.

The significance of birth outcomes lies in their potential long-term consequences. Research by [Bharadwaj et al. \(2018\)](#) indicates that children with lower birth weights are more likely to rely on social insurance programs, such as unemployment and sickness benefits, and that birth weight is a critical factor in adult mortality. Similarly, the impact of birth weight on cognitive development remains relatively stable throughout a child’s educational journey ([Figlio et al., 2014](#)). Additionally, later outcomes—including height, BMI, IQ at age 18, education, and earnings—are also influenced by birth weight ([Black et al., 2007](#)). Moreover, a lower proportion of very low birth weight young adults compared to their normal birth weight counterparts have graduated from high school, and mental health issues during early childhood significantly affect outcomes related to adult socioeconomic status ([Currie et al., 2010](#); [Hack et al., 2002](#)).

Previous studies, such as the one conducted by [Camacho \(2008\)](#) on landmines in Colombia, have explored the effects of explosions on birth outcomes. This study focused on the period from 1998 to 2003, analyzing mines that detonated in the municipality of the mother’s residence during specific trimesters and the corresponding births within that timeframe. In contrast, our research utilizes a more extensive dataset covering the period with the highest incidence of explosions in the country. Given that Colombian municipalities can be large, generalizing exposure measures for the entire population may lead to overestimation of the results, as the impact of proximity to an explosion varies significantly. Therefore, we conduct our analysis at the health provider level, selecting relevant explosions for the births. The prior study reported a significant decrease of 8.7 grams in birth weight for infants experiencing in utero stress due to landmine explosions in their municipality of residence. Rather than examining continuous birth weight data, we focus on low birth weight, allowing for comparisons with other studies and aligning with relevant literature. Additionally, we investigate the effects on very low birth weight, premature, and heterogeneous outcomes based on the mother’s education, marital status, and age.

We contribute to the research fields of the economics of crime and conflict, political economy, and health. First, our work enhances the literature on crime, particularly regarding the consequences of landmines and conflict in Colombia ([Romero and Garcia, 2017](#); [Vargas et al., 2023](#)). Specifically the effect of armed conflict on the health outcomes in Colombia ([Camacho, 2008](#); [Duque, 2017](#); [Kreif et al., 2022](#)). Secondly, we advance the understanding of the relationship between stress-inducing situations and birth outcomes. Previous research has documented an increase in births with complications during periods of conflict in Catalonia ([Bravo and Castello, 2021](#)), as well as lower birth weights following acts of terrorism ([Goin et al., 2020](#); [Mansour and Rees, 2012](#); [Quintana-Domeque and Ródenas-Serrano, 2017](#)) and an association with smaller and earlier births ([Endara et al., 2009](#)). Additionally, the aftermath of the 9/11 events has been shown to impact newborns, particularly boys ([Currie and Schwandt, 2016](#)), while exposure to assaults ([Currie et al., 2022](#)) and homicides in residential areas ([Torche and Villarreal, 2014](#)) are linked to adverse outcomes.

In the health literature, we first contribute to understanding the effects of maternal stress on newborns. Research on fetal origins suggests that mild shocks during early life can lead to significant negative impacts on health outcomes (Almond and Currie, 2011; Almond et al., 2018). Maternal psychological factors can play a critical role in pregnancy complications and negatively influence the development of the unborn child (Mulder et al., 2002). Such stress is associated with a notable decline in birth weight and an increase in the prevalence of low birth weight (Torche, 2011). These adverse conditions during prenatal development can have lasting implications for individuals' future outcomes. Birth weight, for instance, is positively correlated with permanent income and earnings throughout various stages of life (Bharadwaj et al., 2018), cognitive development (Figlio et al., 2014), labor market outcomes, and overall socioeconomic status (Black et al., 2007; Hack et al., 2002).

2. Context

2.1. Violence and landmines

Colombia has faced frequent internal turmoil since gaining independence from Spain in the early 1800s. The most recent civil war officially dates to the mid-1960s, when *the Revolutionary Armed Forces of Colombia* and *the National Liberation Army* (FARC and ELN from their Spanish acronym) were founded. During the subsequent twenty years, additional guerrilla groups, albeit smaller in size, arose alongside right-wing paramilitary organizations. These paramilitary groups were initially supplied with weapons by the state in the early 1970s and trained as self-defense groups.

Both the paramilitary factions, which united under the umbrella organization known as the *United Self-Defense of Colombia* (AUC) in 1997, and the guerrilla groups frequently victimize civilians to gain territorial dominance. The tactic of victimizing civilians as a means of gaining territorial control is commonly observed in civil wars. Another prevalent approach employed by armed groups in securing their strongholds and safeguarding illegal crops is the use of anti-personnel landmines. Colombia, in particular, has one of the highest number of victims of improvised anti-personnel mines, with over 12,000 individuals directly impacted by these devices since 1999 (Coalition et al., b)

The use of landmines in the Colombian conflict can be traced back to the 1970s when the government imported a significant number of anti-personnel mines to safeguard important military bases from guerrilla attacks. The majority of these mines were planted during the 1980s. However, the most significant development in the creation and deployment of improvised mines in Colombia occurred in 2008 when FARC's secretariat initiated a strategy known as the Revolutionary Rebirth of the Masses or Plan Renacer Revolucionario de las Masas. As of 2017, the estimated size of land in Colombia contaminated with landmines was approximately 11,400 acres (Coalition et al., a).

In the [Figure 4](#) is possible see the most affected periods in victims by landmines. From 2007 the victims started to reduce. Also, it is possible to see that the number of births affected for a landmine near the hospital that was delivered, goes up until 2009. In the [Figure 1](#) the most affected municipalities are concentrated in the eastern and southern regions of the country, as well as along the Pacific coast. The high effectiveness of landmines in military combat against the state and their low cost are two reasons why their use has proliferated.

Indeed, for every two combatants who fall victim to a landmine, a civilian does as well. Of the 10,189 victims recorded by PAICMA between 1982 and 2012, 3,885 were civilians (38%) and 6,304 were members of the armed forces (62%), highlighting the indiscriminate impact of this type of weapon. Thus, for every two combatants who fall victim to a landmine, one civilian also does. In fact, children and adolescents are the primary victims of this type of weapon, with 995 of the 3,885 civilian victims belonging to this age group. Also, the division for gender of the victims is around 49.5% for women ([Grupo de Memoria Histórica, 2021](#)).

2.2. Newborn Health

In Colombia, the Constitution and laws, including statutory laws, recognize pregnant women as subjects of special protection under Article 11. They are guaranteed access to prenatal care during pregnancy, specialized care during childbirth, and support in the early weeks postpartum. The characteristics of mothers and births are shown in [Table 1](#). At the national level, the average number of prenatal check-ups is 9.54, while in our sample it is 9.87. On average, the number of live births per woman is two. Nationally, most mothers are married or in de facto unions. However, in our sample, the majority are single. The most common type of delivery is spontaneous. The age range with the highest number of births is between 20 and 34 years old. Most mothers have a high school education or lower. Additionally, there is a balance between the number of boys and girls born.

According to the 2015 DHS (Demographic and Health Survey), among women aged 13 to 49 who had a live birth in the five years preceding the survey, there was a slight increase in institutional childbirth care (96.9%). Of the total births attended by professionals (95.9%), there were generally high levels of care, with a notable difference between urban (99.0%) and rural areas (88.1%) ([ICF, 2015](#)).

Colombia operates a mandatory public health system funded by payroll taxes and general taxation. This system provides free coverage for all maternity and early childhood care. The public sector in Colombia finances 75.2% of total health expenditures, while households contribute 15.9% through out-of-pocket payments, one of the lowest rates among OECD countries ([Pérez-Valbuena, 2015](#)). According to the Minister of Health and Social Protection in 2022, Colombia's healthcare system has achieved 99.6%

universal insurance coverage through the General System of Social Security in Health ([Ministry of Health and Social Protection, 2023](#))

A major concern for victims is the risk of not having health insurance affiliation. However, the opposite is true. In December 2021, a cross-reference of the Single Victim Registry and the Single Affiliates Database revealed that 94.5% of victims of the armed conflict were enrolled in the General Social Security System in Health.

Nearly all newborns are weighed at birth. In the national population, the rate of low birth weight was 8.67%, with 1.07% of births classified as very low birth weight, and 18% of births were premature. These variables closely resemble the findings in our sample.

3. Data

In this section, we provide an overview of the primary data sources and the methods used to measure exposure and the main outcome variables. Additionally, we incorporate supplementary datasets to evaluate the robustness of our identification assumptions and explore potential causal mechanisms. The sample is restricted to municipalities that experienced a landmine explosion at some point, as well as health providers located within a 15-km radius of these explosions. Colombia comprises 1,104 municipalities with recorded births, but our sample focuses on 294 municipalities, as illustrated in [Figure 1](#). We limit our analysis to births with conception dates between 2002 and 2017.

3.1. Vital Statistics and Health Providers

Annual birth data are collected by DANE, Colombia’s National Statistical System. DANE consolidates this information through birth certificates that can be submitted in either digital or physical format. Birth registration requires the presentation of a certificate of live birth, which is issued by the attending medical staff. The birth records consist of three sections: (1) newborn data, including birthweight, gestational age, and height; (2) parental characteristics, such as number of live-born children, type of delivery, and date of the mother’s previous birth; and (3) information about the individual certifying the birth and the healthcare provider.

We geo-referenced the vital statistics data and built a birth-level dataset for the years 2003 to 2017, covering conception dates from 2002 to 2016. This dataset includes birth characteristics, maternal information, and the coordinates of healthcare providers. Since the vital statistics database reports gestational age in ranges, we use the midpoint of each range for analysis. Furthermore, as only the month and year of birth are recorded, we assume that all births occurred on the first day of the respective month.

Our primary outcomes of interest are health indicators, including low birthweight, very low birthweight, and premature birth. Due to anonymization procedures, we cannot observe continuous measures such as weeks of gestation or birth weight. Additionally, data restrictions prevent access to a maternal identifier, making it impossible to link maternal data with exposure information at the individual level. Consequently, we are unable to analyze outcomes within mothers or households. Our sample consists of 3,029,346 births. [Figure 4](#) shows the number of births affected each year.

We also use administrative data from the Ministry of Health, Registro Especial de Prestadores de Servicios de Salud (REPS)¹, which provides detailed information on healthcare providers, including unique identifiers, characteristics, and geospatial coordinates. This allows us to geolocate healthcare providers and link them to the birth data. [Figure 2](#) illustrates the geographic distribution of health providers across Colombia. For our analysis, we limit the sample to healthcare providers located within a 15-km radius of a landmine explosion at any point during the study period.

To estimate trimester-specific exposure to explosions, we use the "expected" birthdate instead of the actual birthdate. This approach accounts for the potential impact of stress from explosions on gestational length, which could otherwise introduce bias. The first trimester is defined as 0 to 91 days post-conception, the second trimester as 92 to 182 days, and the third trimester as 183 to 280 days ([Black et al., 2016](#); [Currie et al., 2022](#)).

3.2. Landmines and explosions

Colombia ratified the Ottawa Convention in 1997, prohibiting the use, storage, production, and transfer of anti-personnel mines. In 2002, the country implemented the Information Management System for Mine Action (IMSMA), developed by the Geneva International Centre for Humanitarian Demining (GICHD). IMSMA is a comprehensive database that records instances of landmine explosions and other explosive devices, suspected areas of landmine presence, and demining activities. It provides geo-located information on landmine explosions dating back to 2001, with details about each incident, including a description of the event, the suspected party responsible for placing the landmine, and information about the victims (such as their gender, age, civilian or military status, and the severity of their injuries).

[Figure 1](#) shows the spatial distribution of the 5,974 landmine explosions recorded between 2002 and 2017. The most affected municipalities are concentrated in the eastern and southern regions of the country, as well as along the Pacific coast. [Figure 4](#) highlights the years with the highest frequency of explosions, with a peak in 2006 and a significant number of incidents occurring between 2002 and 2012.

¹This is an updated database based on the data provided by Mauricio Romero, which includes a comprehensive list of all medical providers (e.g., hospitals, clinics, private practices) along with their GPS coordinates. The update was performed using data from <https://prestadores.minsalud.gov.co/habilitacion/>

In our sample, we include healthcare providers located within a 15-kilometer radius of a landmine explosion. By georeferencing these explosions and constructing buffers around each health facility, we identify which providers were affected by an explosion within this range. This radius allows us to capture both rural and urban settings while focusing on the most relevant explosions. Although no national measure exists regarding the average distance women travel to give birth, a 15-kilometer radius encompasses a sufficiently broad area for our analysis. To demonstrate robustness, we also test alternative radius sizes. Importantly, a single explosion can affect multiple healthcare providers, and conversely, a single provider may be impacted by multiple explosions. [Figure 3](#) illustrates the construction of these buffers and their intersection with recorded landmine explosions.

On the vital statistics side, we have trimester-specific pregnancy dates, which we match with the dates of landmine explosions to determine exposure. A birth is classified as affected based on the trimester in which the explosion occurred. Some births were exposed in all trimesters, some in just one, while others were not exposed but remained in high-risk areas throughout the pregnancy.

4. Empirical Strategy

To estimate the causal effects of exposure to landmine explosions on infant health outcomes, we exploit within-health provider variation. The Vital Statistics data do not contain the exact date of birth or precise information on gestational weeks. Instead, the data provide gestational age ranges, and we use the midpoint of each range for our analysis. Additionally, the data include information on the month and year of birth, but not the specific day. For consistency, we assume the first day of the month as the birth date. Using this information, we estimate the conception date by subtracting the gestational length from the recorded birth date, following methods used in previous literature ([Black et al., 2016](#); [Currie et al., 2022](#)). We exploit both the timing of explosion events as well as their exact geo-referenced location and the geo-referenced location of each health provider.

In our main specification, we only keep explosions that occurred within a 15Km radius of a health center. We then test the robustness of this choice. Our main estimation equation takes the form:

$$y_{iht} = \beta_1 \times Tri_{ht}^1 + \beta_2 \times Tri_{ht}^2 + \beta_3 \times Tri_{ht}^3 + \gamma X_{iht} + \alpha_h + \alpha_t + \epsilon_{iht} \quad (1)$$

where y_{ihmt} are different measures of birth characteristics for a child i , born in health provider h , and conceived during month-year t . The variables Tri_{ht}^k ($k = 1, 2, 3$) capture trimester-specific exposure of the mother to an explosion. Each Tri_{ht}^k is a dummy variable that takes the value of one if, during the corresponding trimester, health provider h where the mother gave birth was affected by an explosion. X_i

is an array of control variables related to maternal characteristics, including the mother’s age, education level, marital status, birth multiplicity, number of children born alive, social security coverage, and type of delivery. α_h are health providers fixed effects and α_t are conception month-year fixed effects. ϵ_{iht} is an error term clustered at the health provider level.

Our parameters of interest, β_1 , β_2 , and β_3 , capture the differential change in the birth outcomes of children of mothers who were exposed to landmine explosion during the different trimester of pregnancy, relative to the outcomes of children of mothers who gave birth in the same hospital, it means they were in risk zones, but they were not exposed to an explosion during pregnancy.

The landmines are strategically deployed across various municipalities, and our sample is restricted to those that experienced a landmine explosion at some point between 2002 and 2017. We further restrict the sample to health providers located within a 15-km radius of these explosions. The sample captures births in areas at risk of explosions, where the timing and probability of explosions are presumably random and beyond any control from the armed group. Our analysis focuses on a cross-section of mothers who gave birth during this period. The methodology relies on a random assignment framework, conditional on unobservable factors, within the same healthcare provider and month-year of conception. These unobservable factors may include the mothers’ daily mobility patterns or their level of exposure to the noise from the explosion when it occurred. Conditional on these unobservables, differences in birth outcomes are attributed solely to the exposure to the landmine explosion.

5. Results

This section discusses our estimated results. We describe the main findings regarding the impact of landmine explosions on birth outcomes.

5.1. The effect of landmine explosions on birth outcomes

In [Table 2](#), we present our main findings on the impact of anti-personnel landmine explosions on newborn health outcomes. These results are derived from estimating equation (1). Columns (1), (3), and (5) include fixed effects at the health provider level and time fixed effects, while Columns (2), (4), and (6) add municipality-year fixed effects. Both analyses incorporate maternal controls.

The estimates are robust across specifications. We find that exposure to explosions during the first trimester of pregnancy leads to a statistically significant increase of 2.72 percent in the probability of low birth weight. Similarly, using municipality-year fixed effects, we observe an increase of 4.34 percent. For the other trimesters, we do not find any significant effects. Additionally, the probability of very low birth weight increases by 4.61 percent when the mother is exposed during the first trimester. Regarding

gestational weeks, exposure to explosions during the third trimester raises the likelihood of premature birth by 3.92 percent. Since no significant effect is observed for explosions during the first trimester on gestational weeks, this result is interpreted as a placebo. A premature birth in this trimester would most likely be classified as a miscarriage rather than an early delivery, making the absence of an effect consistent with theoretical expectations.

We also estimate the effect of the number of landmine explosions to which the mother was exposed. The results, shown in [Table 3](#), indicate that exposure during the first trimester significantly increases the probability of low birth weight. A similar effect on prematurity is observed in the third trimester. For very low birth weight, the coefficients for the first and third trimesters are similar, but only the coefficient for the third trimester is significant at the 0.10 level. The strength of the effect based on the number of explosions, however, does not show a clear pattern.

Furthermore, in [Table 4](#), when analyzing the mother's educational level, we observe that women with more than a primary education have a higher likelihood of having a baby with low birth weight when exposed to stress in the third trimester, although this result is not robust across all specifications. Regarding marital status, single mothers are more likely to have a baby with low birth weight if exposed during the first or second trimester. No significant differences were observed in relation to maternal age. Similarly, in [Table 5](#) we found no significant differences in the likelihood of cesarean sections. However, exposure to stress during the second trimester is associated with an increase in the number of prenatal check-ups, while a reduction in prenatal check-ups is observed when exposure occurs in the third trimester.

The impact of exposure varies depending on the trimester in which the mother was exposed. Stress and physiological mechanisms operate differently across pregnancy stages. This is evident in [Table 6](#), where no significant results are found for any outcomes, though the positive coefficients suggest worse health outcomes for newborns.

When comparing our results with [Camacho \(2008\)](#), we observe that both studies use similar data but different strategies. While she uses the mother's municipality of residence, we focus on the location of the health provider. Although her paper does not report results on low birth weight, she analyzes the continuous variable of birth weight and finds a reduction in early pregnancy. When we replicate her strategy showed in [Table 7](#) within the same time frame, we find a 4.51 percent increase in the probability of low birth weight during the first trimester.

To better understand the magnitude of the coefficients, it is important to note that our estimates rely on health provider-level variation and are therefore highly localized. Moreover, the perception of explosions might not be significant if the mother was unaware of the event at the time. Factors such as geography, noise, weather, and the dissemination of information are crucial in determining awareness. Additionally,

explosions tend to be brief and infrequent compared to other stressors that may occur over a prolonged period. Less than 35% of the sample of mothers who were ever exposed experienced more than one explosion during their pregnancy.

To contextualize our findings within the existing literature, we compare the magnitudes of effects observed in previous studies. For instance, [Currie et al. \(2024\)](#) report that mass shootings occurring during the first trimester of pregnancy are associated with a 5.7% increase in the likelihood of low birth weight and a 5.2% increase in the incidence of extreme prematurity. These effect sizes are comparable to our findings, likely due to the transient nature of mass shootings. In contrast, [Mansour and Rees \(2012\)](#) note that a fatality occurring 9–3 months before birth correlates with a mere 0.0013 increase in the probability of having a low-birth-weight child. Additionally, [Currie et al. \(2022\)](#) find that exposure to domestic violence significantly increases the likelihood of very low birth weight by 61% and the likelihood of very premature birth by 32%.

6. Mechanisms

6.1. The effect of landmine explosions on birth outcomes

The explosion of an antipersonnel mine affects mothers differently depending on the trimester of pregnancy during which it occurs. The outcomes could be driven by the stress caused by the fear of a potential explosion. Explosions may signal the presence of risks in the area, such as the activity of illegal armed groups, which induces fear in the population ([Vargas et al., 2023](#)). This fear can translate into stress and elevated cortisol levels. Placental corticotropin-releasing hormone (CRH) is recognized as one of the key endocrine mediators of spontaneous labor and possibly fetal development. CRH plays a central role in regulating the activity of the hypothalamic-pituitary-adrenal (HPA) axis, which governs the body’s physiological response to stress ([Wadhwa et al., 2004](#)).

Our findings align with the existing literature, suggesting that each explosion increases CRH levels and affects the regulation of pregnancy duration and fetal maturation. In our study, when the mother was exposed to a landmine explosion during the first trimester, there was a higher likelihood of delivering a low birth weight baby. The health literature supports this, showing that maternal psychosocial factors during the first trimester are associated with an increased risk of low birth weight ([Paarlberg et al., 1999](#)). The risk is particularly high during the first three months of pregnancy. Additionally, when the mother was exposed to an explosion during the third trimester, the likelihood of preterm delivery increased. Maternal plasma levels of corticotropin-releasing hormone have been found to be significantly elevated as early as 18 to 20 weeks of gestation in women who subsequently delivered preterm ([Hobel et al., 1999](#)).

Our results are robust across different buffer sizes around the health provider. A 10 km buffer allows for coverage of a larger area near the health provider. In [Table 8](#), we present the results for the three main outcomes. The results are more similar between the 10 km and 15 km buffers. For easier comparison of the effects in the first trimester of pregnancy on low birthweight, we show each estimate with a 95% confidence interval in [Figure 6](#). Additionally, we check the robustness to influential observations for municipalities in [Figure 5](#).

We also find [Table 4](#) that when a woman is single, the birth outcomes of her baby tend to be worse. This finding is supported by literature that associates a mother’s characteristics, such as depressive symptoms or social pressure related to not having a partner, with adverse birth outcomes. Single mothers may face additional stressors, such as having only one income or coping with other social difficulties ([Paarlberg et al., 1999](#)). Conversely, women who have a partner experience different outcomes, as prenatal reports of effective social support from a partner (in terms of both quality and quantity) predict lower anxiety levels in mid-pregnancy and reduced anxiety and depressive symptoms from pregnancy to postpartum ([Dunkel Schetter, 2011](#)).

7. Conclusions

Calculating the effects of armed conflict strategies on populations, particularly those who have not yet been born, poses significant challenges. These challenges are exacerbated by the complexities of measuring the indirect consequences of violence on maternal and child health outcomes. This paper addresses these intricacies by examining the birth outcomes resulting from quasi-random explosions in Colombia. Notably, these explosions are not specifically aimed at influencing birth outcomes or targeting mothers in proximity to the blasts, nor are they strategically located with consideration for future births. Instead, they represent an unpredictable element of armed conflict that can have far-reaching implications for civilian populations.

To rigorously identify the effects of these explosions on new births, we compare children born to mothers exposed to landmine explosions during pregnancy with those of mothers who gave birth in the same hospitals but were not exposed to such traumatic events. Our findings indicate that when mothers are exposed to explosions during early pregnancy, their newborns are significantly more likely to have low birth weight, which is a critical indicator of health and development. Conversely, exposure during late pregnancy correlates with an increased likelihood of premature births. The primary potential mechanism underlying these adverse outcomes appears to be maternal stress induced by the violent experience of landmine detonations, which can disrupt the physiological processes essential for healthy fetal development.

The presence of stressful situations during pregnancy is shown to have profound impacts on birth outcomes. Specifically, low birth weight and prematurity can have long-term consequences that extend well beyond infancy. Research has indicated that these outcomes are linked to increased adult mortality rates, impaired cognitive development, and negative socioeconomic outcomes, including lower educational attainment and diminished labor market performance. The implications of these findings underscore the necessity for women to develop effective coping mechanisms to manage stress throughout the entire pregnancy, particularly when they are situated in conflict-affected areas.

Furthermore, this study highlights the importance of providing adequate support and resources for expectant mothers living in high-conflict regions. Addressing maternal stress not only has the potential to improve immediate birth outcomes but also serves as a critical investment in the long-term health and well-being of future generations. In light of these findings, it is imperative to consider comprehensive public health interventions that can mitigate the adverse effects of armed conflict on maternal and child health.

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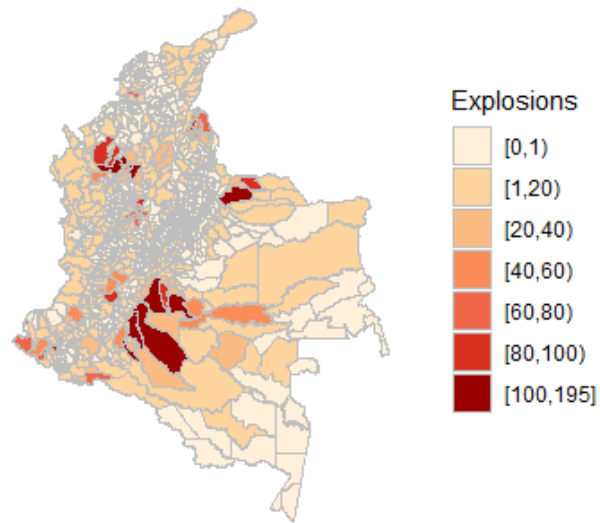
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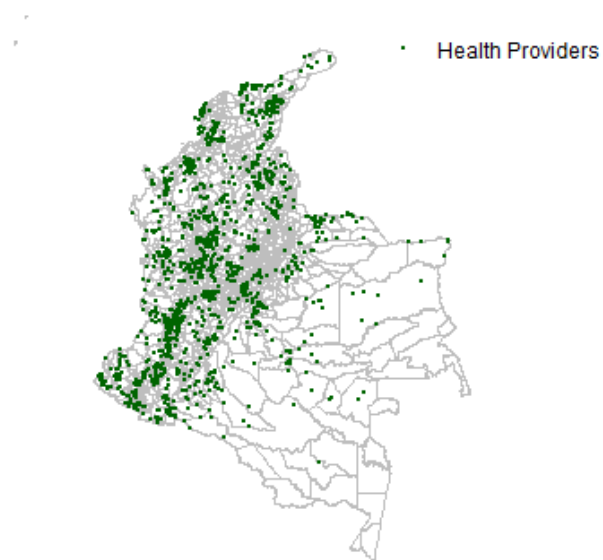
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Figure 1: Geographic Distribution of Landmine Explosions



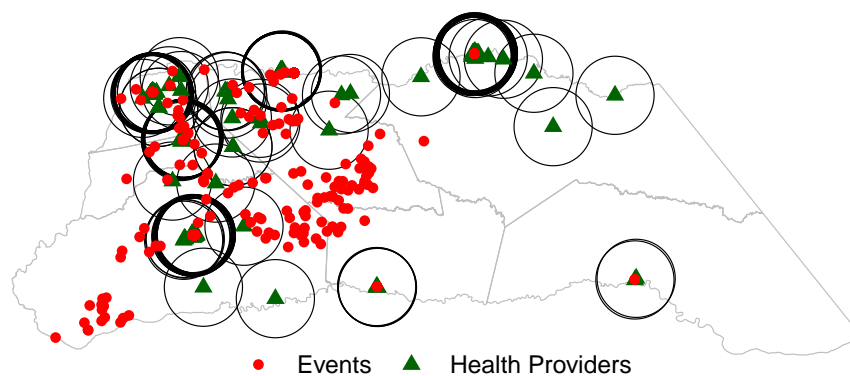
Notes: This figure shows the spatial distribution of explosions between 2002 and 2017 in Colombia. Municipalities with the lightest color were not exposed to any landmine explosions.

Figure 2: Geographic Distribution of Health Providers



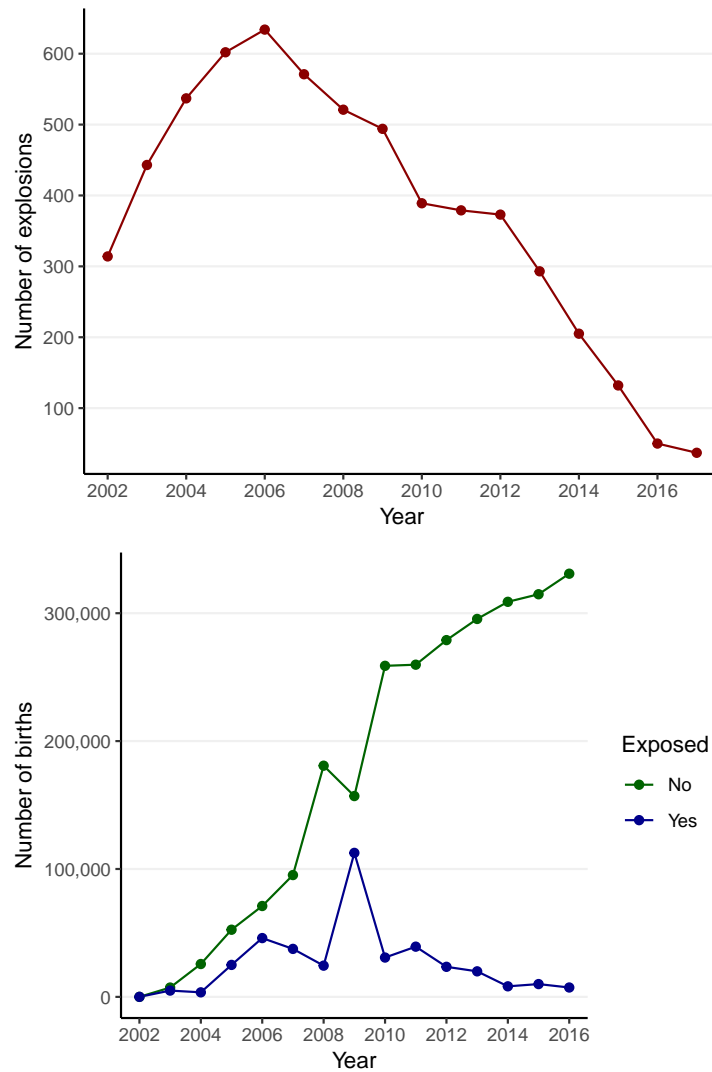
Notes: This figure shows the spatial distribution of the health providers in Colombia.

Figure 3: Geographic Distribution in Arauca



Notes: This figure illustrates the precise locations of the landmines explosions that occurred between 2002 and 2017 in the department of Arauca. Green triangles are the health providers. Black circles on the map denote a 15-km radius around each institution, calculated based on the latitudes and longitudes of the health providers. This is before we chose our sample with only health providers who were affected. For the circles that don't have any health provider in the figure, the health provider is located in another municipality. These are not taken into account within the municipality if the health provider belongs to a different one.

Figure 4: Characteristics of National Level Landmines Explosions and Births



Notes: The top panel of this figure presents a graphical representation of the explosions between 2002 and 2017. The data sources utilized for this analysis is The Information Management System for Mine Action (IMSMA) data. The bottom panel plots the births according to the conceptional date between 2002 and 2016 based on The Vital Statistics Natality records.

Table 1: Summary Statistics

	Sample	National
Panel A: Control Variables		
%		
<i>Mother's Age</i>		
10-19	22.34	22.51
20-34	67.05	67.09
35-54	10.52	10.04
<i>Type of Delivery</i>		
Spontaneous	57.25	58.82
Cesarean Section	41.10	39.69
Other	1.64	1.49
<i>Multiplicity of birth</i>		
Simple	97.94	97.66
Multiple	2.06	2.34
<i>Marital Status</i>		
Single	42.80	35.21
Married or in the facto unions	25.37	41.48
Other	29.95	21.06
<i>Mother Education</i>		
None	3.33	2.80
High School or Less	73.65	77.98
More than High School	9.08	9.48
<i>Sex</i>		
Female Child	48.63	48.61
#		
Children Born Alive	2.06 (4.13)	2.59 (7.66)
Prenatal Check-ups	7.56 (11.30)	9.54 (17.77)
Total Pregnancies	2.25 (4.26)	2.74 (7.41)
Panel B: Outcome Variables		
Low Birthweight	9.87	8.67
Very Low Birthweight	1.29	1.07
Premature	19.88	17.99
Observations	3,100,052	9,697,690

Notes: This table presents summary statistics for several controls and outcome variables using Vital Statistics Natality records from Colombia between 2003 to 2017. The first set of controls includes categorical variables, with values presented as percentages of the sample. The last set of controls includes continuous variables, with values presented as sample averages. The outcome variables are categorical variables, with values presented as percentages of the sample. Column 1 displays the values for the corresponding variables within a 15km radius of the closest explosion to a health provider. Column 2 displays the values for the corresponding variables at national level.

Table 2: Impact of Landmine Presence on Health Outcomes

	Low Birthweight		Very Low Birthweight		Premature	
	(1)	(2)	(3)	(4)	(5)	(6)
Exposure in the 1st Trimester	0.0027** (0.001)	0.0043*** (0.001)	0.0006* (0.000)	0.0008* (0.000)	0.0007 (0.002)	0.0032 (0.003)
Exposure in the 2nd Trimester	-0.0007 (0.001)	0.0021 (0.001)	-0.0001 (0.000)	0.0002 (0.000)	0.0018 (0.002)	0.0046 (0.003)
Exposure in the 3rd Trimester	0.0018 (0.001)	0.0035* (0.002)	0.0006 (0.000)	0.0005 (0.000)	0.0078*** (0.003)	0.0098** (0.004)
Observations	3029241	3029172	3029241	3029172	3029241	3029172
Mean	0.099	0.099	0.013	0.013	0.199	0.199
SD	0.298	0.298	0.113	0.113	0.399	0.399
Conception Month-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality-Year FE	No	Yes	No	Yes	No	Yes
Mother Characteristics	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The outcome in the first group of columns is low weight (less than 2,500g), in the second group is very low weight (less than 1,500g) and in the third group is premature (less than 37 weeks of gestation). The estimates presented represent the exposure to landmine explosions in each trimester of pregnancy. The mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during each trimester of her pregnancy. Mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during any moment of her pregnancy. Exposure in the first trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the first trimester of pregnancy. Exposure in the second trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the second trimester of pregnancy. Exposure in the third trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the third trimester of pregnancy. Standard errors are clustered at the health provider level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Impact of the Number of Landmines on Health Outcomes

	(1)	(2)	(3)
	Low Birthweight	Very Low Birthweight	Premature
N. Explosions in the 1st Trimester	0.0017*** (0.001)	0.0003 (0.000)	0.0003 (0.001)
N. Explosions in the 2nd Trimester	-0.0010 (0.001)	-0.0002 (0.000)	0.0002 (0.001)
N. Explosions in the 3rd Trimester	0.0010 (0.001)	0.0003* (0.000)	0.0041*** (0.001)
Observations	3029241	3029241	3029241
Mean	0.099	0.013	0.199
SD	0.298	0.113	0.399
Conception Month-Year FE	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes

Notes: The outcome in the first column is low weight (less than 2,500g), in the second column is very low weight (less than 1,500g) and in the third column is premature (less than 37 weeks of gestation). The estimates presented represent the exposure to landmine explosions in each trimester of pregnancy. The mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during each trimester of her pregnancy. Mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during any moment of her pregnancy. Exposure in the first trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the first trimester of pregnancy. Exposure in the second trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the second trimester of pregnancy. Exposure in the third trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the third trimester of pregnancy. Standard errors are clustered at the health provider level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Heterogeneous Effects on Health Outcomes

	(1) Low Birthweight	(2) Very Low Birthweight	(3) Premature
<i>Panel A: Education</i>			
Exposure 1st Trim.	0.0030* (0.002)	0.0008 (0.001)	-0.0016 (0.003)
Exposure 1st Trim. × Primary	0.0002 (0.002)	-0.0001 (0.001)	0.0038 (0.003)
Exposure 2nd Trim.	0.0008 (0.002)	0.0003 (0.001)	0.0021 (0.003)
Exposure 2nd Trim. × Primary	-0.0029* (0.002)	-0.0011* (0.001)	-0.0023 (0.003)
Exposure 3rd Trim.	0.0047** (0.002)	0.0011* (0.001)	0.0117*** (0.004)
Exposure 3rd Trim. × Primary	-0.0055** (0.002)	-0.0009 (0.001)	-0.0079** (0.003)
Observations	2607017	2607017	2607017
Mean	0.099	0.013	0.199
SD	0.298	0.113	0.399
Conception Month-Year FE	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes
<i>Panel B: Marital Status</i>			
Exposure 1st Trim.	0.0016 (0.001)	0.0008* (0.000)	-0.0004 (0.002)
Exposure 1st Trim. × Single	0.0032* (0.002)	-0.0001 (0.001)	0.0024 (0.002)
Exposure 2nd Trim.	-0.0025 (0.002)	-0.0000 (0.000)	0.0002 (0.003)
Exposure 2nd Trim. × Single	0.0043*** (0.002)	-0.0003 (0.001)	0.0039 (0.003)
Exposure 3rd Trim.	0.0023 (0.002)	0.0005 (0.000)	0.0111*** (0.003)
Exposure 3rd Trim. × Single	-0.0013 (0.002)	0.0002 (0.001)	-0.0073** (0.003)
Observations	2972058	2972058	2972058
Mean	0.099	0.013	0.199
SD	0.298	0.113	0.399
Conception Month-Year FE	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes

	(1)	(2)	(3)
	Low Birthweight	Very Low Birthweight	Premature
<i>Panel C: Age</i>			
Exposure 1st Trim.	0.0015 (0.002)	0.0007 (0.001)	0.0028 (0.002)
Exposure 1st Trim. × Age: 20-34	0.0019 (0.002)	-0.0000 (0.001)	-0.0028 (0.002)
Exposure 1st Trim. × Age: 35-54	-0.0002 (0.004)	-0.0008 (0.001)	-0.0025 (0.004)
Exposure 2nd Trim.	-0.0004 (0.002)	0.0001 (0.001)	0.0023 (0.003)
Exposure 2nd Trim. × Age: 20-34	-0.0005 (0.002)	-0.0003 (0.001)	-0.0004 (0.002)
Exposure 2nd Trim. × Age: 35-54	0.0010 (0.003)	-0.0001 (0.001)	-0.0017 (0.004)
Exposure 3rd Trim.	-0.0001 (0.002)	0.0008 (0.001)	0.0079** (0.004)
Exposure 3rd Trim. × Age: 20-34	0.0025 (0.002)	-0.0002 (0.001)	-0.0003 (0.003)
Exposure 3rd Trim. × Age: 35-54	0.0030 (0.004)	-0.0008 (0.001)	0.0001 (0.005)
Observations	3026936	3026936	3026936
Mean	0.099	0.013	0.199
SD	0.298	0.113	0.399
Conception Month-Year FE	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes

Notes: The outcome in the first column is low weight (less than 2,500g), in the second column is very low weight (less than 1,500g) and in the third column is premature (less than 37 weeks of gestation). Standard errors are clustered at the health provider level. * $p < 0.10$, ** $p < 0.05$, ***, $p < 0.01$.

Table 5: Other Effects on Health Outcomes

	(1) Caesarean section	(2) Number of controls
Exposure in the 1st Trimester	-0.0002 (0.001)	0.2194 (0.151)
Exposure in the 2nd Trimester	-0.0003 (0.001)	0.2766** (0.135)
Exposure in the 3rd Trimester	0.0006 (0.001)	-0.4200** (0.170)
Observations	3027057	3029241
Mean	0.411	7.562
SD	0.492	11.305
Conception Month-Year FE	Yes	Yes
Health Provider FE	Yes	Yes
Mother Characteristics	Yes	Yes

Notes: The outcome in the first column is a dummy variable indicating whether the birth was delivered by caesarean section, while the second column represents the number of prenatal checkups the mother had during pregnancy. Mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during any moment of her pregnancy. Exposure in the first trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the first trimester of pregnancy. Exposure in the second trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the second trimester of pregnancy. Exposure in the third trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the third trimester of pregnancy. * $p < 0.10$, ** $p < 0.05$, ***, $p < 0.01$.

Table 6: Health Effects of Any Exposure to Landmines

	(1) Low Birthweight	(2) Very Low Birthweight	(3) Premature
Exposure in the pregnancy	0.0015 (0.001)	0.0005 (0.000)	0.0023 (0.002)
Observations	3029241	3029241	3029241
Mean	0.099	0.013	0.199
SD	0.298	0.113	0.399
Conception Month-Year FE	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes

Notes: The outcome in the first column is low weight (less than 2,500g), in the second column is very low weight (less than 1,500g) and in the third column is premature (less than 37 weeks of gestation). The estimates presented represent an overall measure of exposure to explosions during pregnancy. The mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during any moment of her pregnancy. Mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during any moment of her pregnancy. Exposure in the first trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the first trimester of pregnancy. Exposure in the second trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the second trimester of pregnancy. Exposure in the third trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the third trimester of pregnancy. Standard errors are clustered at the health provider level. * $p < 0.10$, ** $p < 0.05$, ***, $p < 0.01$.

Table 7: Differences between papers

	(1) Low Weight	(2) Low Weight
Exposure in the 1st Trimester	0.0027** (0.001)	0.0037** (0.002)
Exposure in the 2nd Trimester	-0.0007 (0.001)	0.0018 (0.005)
Exposure in the 3rd Trimester	0.0018 (0.001)	-0.0023 (0.006)
Observations	3029241	1620978
Mean	0.099	0.082
SD	0.298	0.275
Month-Year FE	Yes	Yes
Health Provider FE	Yes	No
Municipality FE	No	Yes
Mother Characteristics	Yes	Yes

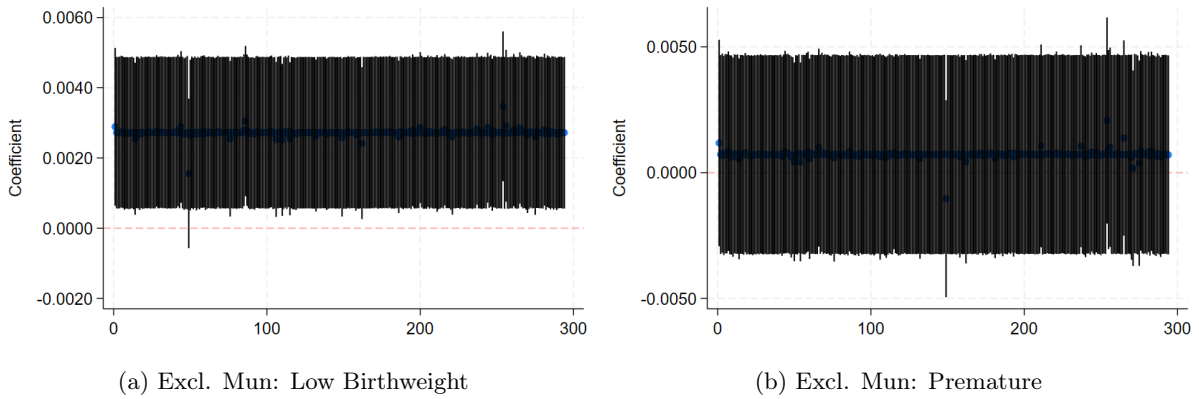
Notes: The column in the first and the second column is low weight (less than 2,500g). The first column shows the results for the equation 1 of this paper. The second column shows the results for Camacho (2008). The sample used in the first model are the births from 2002 to 2017. The sample used in the second model are the births from 1998 to 2003. Time FE in (1) is according to the conception date and in (2) is according to the birth date. Standard errors are clustered at the health provider level in (1) and at the mother municipality level in (2). * $p < 0.10$, ** $p < 0.05$, ***, $p < 0.01$.

Table 8: Robustness Effects

	(1) 5-km	(2) 10-km	(3) 15-km	(4) 20-km
<i>Panel A: Low Weight</i>				
Exposure in the 1st Trimester	0.0011 (0.001)	0.0024* (0.001)	0.0027** (0.001)	0.0023** (0.001)
Exposure in the 2nd Trimester	-0.0006 (0.002)	-0.0011 (0.001)	-0.0007 (0.001)	-0.0002 (0.001)
Exposure in the 3rd Trimester	0.0026 (0.002)	0.0025 (0.002)	0.0018 (0.001)	0.0009 (0.001)
Observations	1833877	2508101	3029241	3138163
Mean	0.085	0.091	0.099	0.098
SD	0.279	0.288	0.298	0.297
Conception Month-Year FE	Yes	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes	Yes
<i>Panel B: Very Low Weight</i>				
Exposure in the 1st Trimester	0.0004 (0.001)	0.0007* (0.000)	0.0006* (0.000)	0.0005 (0.000)
Exposure in the 2nd Trimester	-0.0002 (0.000)	-0.0003 (0.000)	-0.0001 (0.000)	-0.0002 (0.000)
Exposure in the 3rd Trimester	0.0005 (0.000)	0.0002 (0.000)	0.0006 (0.000)	0.0001 (0.000)
Observations	1833877	2508101	3029241	3138163
Mean	0.085	0.091	0.099	0.098
SD	0.279	0.288	0.298	0.297
Conception Month-Year FE	Yes	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes	Yes
<i>Panel C: Premature</i>				
Exposure in the 1st Trimester	0.0003 (0.002)	0.0016 (0.002)	0.0007 (0.002)	0.0011 (0.002)
Exposure in the 2nd Trimester	0.0017 (0.003)	0.0020 (0.003)	0.0018 (0.002)	0.0028 (0.002)
Exposure in the 3rd Trimester	0.0077 (0.005)	0.0091** (0.004)	0.0078*** (0.003)	0.0058** (0.003)
Observations	1833877	2508101	3029241	3138163
Mean	0.085	0.091	0.099	0.098
SD	0.279	0.288	0.298	0.297
Conception Month-Year FE	Yes	Yes	Yes	Yes
Health Provider FE	Yes	Yes	Yes	Yes
Mother Characteristics	Yes	Yes	Yes	Yes

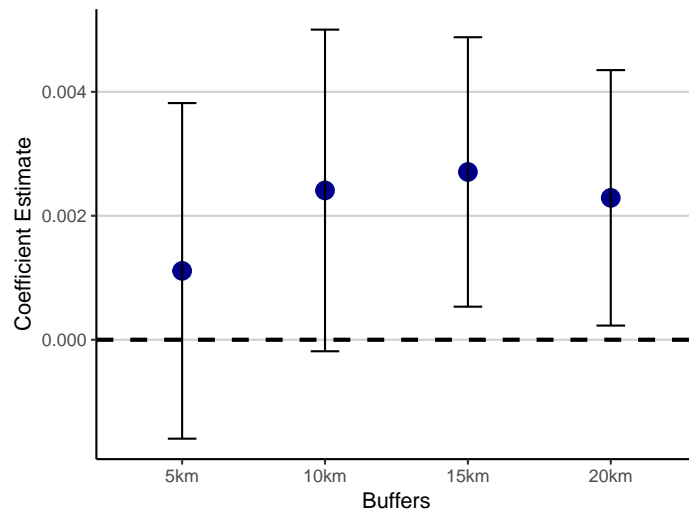
Notes: The estimates presented in (1) use a 5-km buffer, (2) a 10-km buffer, (3) a 15-km buffer, and (4) a 20-km buffer. The outcome in the Panel A is low weight (less than 2,500g), in the Panel B is very low weight (less than 1,500g) and in the Panel C is premature (less than 37 weeks of gestation). Mother's exposure is defined by whether there was an explosion within a specified radius near the hospital where she gave birth, during any moment of her pregnancy. Exposure in the first trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the first trimester of pregnancy. Exposure in the second trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the second trimester of pregnancy. Exposure in the third trimester is a dummy variable equal to 1 if the mother was affected by an explosion during the third trimester of pregnancy. Standard errors are clustered at the health provider level. * $p < 0.10$, ** $p < 0.05$, ***, $p < 0.01$.

Figure 5: Robustness to Influential Observations: Municipalities



Notes: This figure presents the results from equation (1), but excluding one municipality at the time (Panels A and B). We present the point estimate and the confidence interval at the 95% level.

Figure 6: Robustness Distance on the First Trimester Effects



Notes: This figure shows the estimates for low weight in the first trimester of pregnancy, using different radius of buffers. Each coefficient estimate includes the 95% confidence interval. Standard errors are clustered at the health provider level.