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Hunting militias at all cost: Urban military operation and birth outcomes

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ABSTRACT

This study investigates the impact of Operation Orion on newborn health outcomes. While previous research has examined the adverse effects of conflict on child health, the specific consequences of state military operations on newborns, especially in urban settings, remain underexplored. Using a Difference-in-Differences design and administrative data from the Colombian Vital Statistics Reports, we assess the effects of Operation Orion on birth weight, height, prematurity, the likelihood of a high APGAR score, Small for Gestational Age (SGA), and prenatal visits. Our analysis shows a significant reduction in birth weight among infants born in intervention-affected neighborhoods, with the effects most pronounced among infants of married and less educated mothers. We also find a decrease in birth height and a lower probability of an APGAR score above 7, which is indicative of good health at birth. No significant effects are observed for the other outcomes. We discuss maternal stress as the primary mechanism underlying these findings. Our results contribute to a deeper understanding of the complex impacts of state military operations and highlight the need to consider contextual factors when evaluating their effects on local communities.

1. Introduction

In recent years, extensive research has been conducted on the adverse impact of conflict on child health outcomes in Medicine, Economics, and other Social Sciences (Akresh, Verwimp, & Bundervoet, 2011; Brown, 2018; Dagnelie, De Luca, & Maystadt, 2018; Eskenazi, Marks, Catalano, Bruckner, & Toniolo, 2007; Mansour & Rees, 2012; Torche & Shwed, 2015). However, relatively little attention has been given to the impact of State military operations on newborn health outcomes in urban areas. This paper addresses this research gap by examining the effects of Operation Orion, Colombia's largest urban military operation, on several health-related outcomes at birth. Specifically, this study focuses on the effects of the state-led military operation on newborn health outcomes in socio-economically disadvantaged urban areas, which may have unique features and implications compared to other settings.

Colombia's internal armed conflict significantly impacted both urban and rural areas. The conflict affected millions of individuals, involving 16 percent of the total population (about nine million victims). While the conflict was primarily concentrated in rural and small municipalities, it also significantly affected urban areas. One such area was Medellin, Colombia's second-largest city, where several guerrilla groups established a strong presence, particularly in the impoverished *Comuna 13* (also known as *Comuna San Javier*). To regain control of the area, the government launched Operation Orion in October 2002 under the newly elected presidency of Alvaro Uribe. This operation involved approximately 1500 police and army personnel with sophisticated weapons, helicopters, tanks, and other military vehicles. While the government considered the operation a success, little is known about its unintended consequences for newborns in the affected areas.

In our study of Operation Orion's impact on newborn health outcomes, we depart from prior research in several ways. First, rather than examining the adverse effects of non-state armed actors, as in previous studies (Brown, 2020; Camacho, 2008; Eskenazi et al., 2007; Foureaux Koppensteiner & Manacorda, 2016; Mansour & Rees, 2012; Quintana-Domeque & Ródenas-Serrano, 2017; Sherrieb & Norris, 2013), our paper focuses on the unintended consequences of a state military operation. Second, while much of the literature on internal conflict has focused on rural areas (Akresh, Lucchetti, & Thirumurthy, 2012; Akresh et al., 2011; Bundervoet, Verwimp, & Akresh, 2009), we specifically focus on economically disadvantaged urban neighborhoods. Given the high spatial concentration of urban poverty, the potential effects of conflict on these communities may be even more severe.

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Finally, unlike much of the existing literature on urban environments, Operation Orion was a short-term and highly intense counterinsurgency operation that involved tactics and weapons more typical of open-field army confrontations.[1] Notably, violent events associated with Operation Orion were officially labeled as interventions to end the conflict and improve conditions in the targeted neighborhood. This study highlights the need to consider the context of urban conflict and the importance of understanding the state military operations' complex and multifaceted impacts on local communities.

Our study employs a difference-in-differences design (DiD) and administrative data from the Colombian Vital Statistics Reports (VSR) to investigate the impact of Operation Orion on birth outcomes. We aim to identify Operation Orion's causal effect by leveraging the operation's timing and differential exposure among neighborhoods in *Comuna 13* and the rest of Medellin (nearly 240 neighborhoods). Specifically, we focus on newborns conceived between July and October 2002, during the first trimester of pregnancy, when they were potentially affected by Operation Orion. We estimate a standard DiD design and use the Doubly Robust estimators (DR) for DiD research designs proposed by Sant'Anna and Zhao (2020) to account for confounding factors. This approach allows us to incorporate covariates without imposing additional assumptions and combines a regression approach with a re-weighting procedure.

Our analysis reveals significant associations between exposure to Operation Orion during the first trimester of pregnancy and adverse birth outcomes. We find a statistically significant reduction in birth weight by 116.5 grams (g) (relative to the average of 3106 g), a decrease in height by 0.51 centimeters (cm) (relative to the average of 49.3 cm), and a decrease in the probability of having an APGAR score higher than seven by 3 percentage points (pp) (relative to an average of 92 percent). On the other hand, we found no significant effects on the probability of being born premature, the likelihood of being small for gestational age, or the number of prenatal visits the mother attended during pregnancy. As most mothers in the affected neighborhoods were likely to have been exposed to the intervention, our estimates already account for the potential scale-up of its impact, providing insights into the effects of actual exposure to Operation Orion. These results align with those found by Kreif et al. (2022), who focus on the long-run impact of internal armed conflict in Colombia and find effects on height and weight. They identify that most of the impact on children occurs around pregnancy and birth.

To ensure the robustness of our findings, we conducted a series of sensitivity analyses. We estimate the treatment effects using standard DiD, Sant'Anna and Zhao (2020) DR method, and two-way fixed effects models. Across all estimation strategies, our results remain consistent. We examine potential heterogeneous treatment effects across the distribution of newborn health outcomes. In particular, we test whether Operation Orion affected mostly births at the bottom of the distribution (e.g., low birth weight) or if, on the contrary, the results are concentrated in the median part of the distribution. We use the Unconditional Quantile Regression (UQR) approach developed by Firpo, Fortin, and Lemieux (2009). Our analysis indicates that the treatment effects are statistically significant around the median birth weight distribution and between the 25th and 50th percentiles of birth height distribution.

We implement several tests to assess the internal validity of our identification strategy. First, we adopt a neighborhood-month panel approach to mitigate concerns regarding potential biases related to changes in the number of newborns, such as intra-urban migration or fetal mortality, which could affect the composition of treated women. This approach aggregates all the birth registrations in the Colombian VSR by neighborhood and month. Importantly, our analysis reveals that the number of births per neighborhood remained unaffected by Operation Orion, providing evidence that changes in the composition of treated women did not bias our estimates. Second, we employ falsification tests to assess the validity of our findings. Specifically, we simulate a scenario in which the intervention occurred two years before the actual date, and the results demonstrate insignificance, supporting the robustness of our estimates. Third, we conduct a permutation test by randomly assigning the treatment to different neighborhoods 1000 times. The results of this analysis cannot provide sufficient evidence to reject the null hypothesis that random exposure to the state military operation has no impact on birth outcomes. Finally, we ensure the robustness of our inference through the application of the wild bootstrap approach proposed by MacKinnon and Webb (2019) and the randomization inference method developed by MacKinnon and Webb (2020).[2] Our analysis confirms the stability of our findings when subjected to these additional procedures, further strengthening the validity of our results.

Several mechanisms may explain the relationship between Operation Orion and adverse birth outcomes (Kadir, Shenoda, & Goldhagen, 2019). On the one hand, the operation imposed a forced lockdown on residents, which may have affected nutrition and access to health services, leading to adverse birth outcomes because of inadequate food and a lack of medical guidance and supervision (Abu-Saad & Fraser, 2010; Alexander & Korenbrot, 1995). We do not have data on mothers' nutritional status; therefore, we cannot empirically test this mechanism. However, a lack of food does not appear to be the underlying cause of our findings, as the impact of this brief operation on birth weight is concentrated in the middle of the distribution. At the same time, outcomes more sensitive to nutritional effects, such as premature and small gestational age, are unaffected. Concerning limited access to medical care, we use information on the number of prenatal appointments in the VSR data, which we use to assess the potential negative consequences of restricted access to healthcare. Our analysis indicates that Operation Orion has no significant effect on this indicator.

On the other hand, the operation may have heightened stress levels in pregnant women, which could adversely affect fetal health and development (Mulder, Robles de Medina, Huizink, Van den Bergh, Buitelaar, & Visser, 2002). Existing studies suggest that maternal stress during pregnancy is linked to reduced fetal growth and lower birth weight (Wadhwa, Sandman, Porto, Dunkel-Schetter, & Garite, 1993), elevated levels of stress hormones in the fetus (Glynn, Wadhwa, Dunkel-Schetter, Chicz-DeMet, & Sandman, 2001), cognitive and behavioral problems, increased risk of obesity and metabolic disorders, as well as impaired immune function in the offspring (Entringer et al., 2012). Furthermore, maternal stress during pregnancy is associated with a higher likelihood of low birth weight and infant mortality (Davis et al., 2007; Traylor, Johnson, Kimmel, & Manuck, 2020).

Although the VSR data does not directly measure maternal stress or other health indicators for mothers, we have reasonable grounds to believe that maternal stress may have played a role in our specific context. The literature on development provides evidence supporting the idea that maternal stress is a primary pathway through which conflict events may affect the health of both the mother and fetus (Kadir et al., 2019; Spratlen et al., 2022). For instance, medical literature explains the internal mechanism through which maternal stress affects fetal growth and its adequate development (Hobel, Goldstein, & Barrett, 2008; Loomans et al., 2013; Naaz & Muneshwar, 2023; Traylor et al.,

[1] Many authors, such as Conzo & Salustri, 2019; Grossman, Khalil, & Ray, 2019; Hameed, Rahman, & Khanam, 2023; Kreif, Mirelman, Suhrcke, Buitrago, & Moreno-Serra, 2022; Poveda & Martínez, 2023, have studied long-term conflicts. However, there is also literature concerning short-term operations or attacks, such as the World Trade Center Disaster (Brown, 2020; Eskenazi et al., 2007; Spratlen et al., 2022) and the Catalonia attacks in Spain (Armijos Bravo & Vall Castelló, 2021).

[2] See Roodman, Nielsen, MacKinnon, and Webb (2019) for further details on the implementation of MacKinnon and Webb (2020)'s randomization inference method.

2020). Furthermore, anecdotal evidence and testimonies support the intense psychological pressure inflicted on the residents of *Comuna 13* during Operation Orion (Aricapa, 2017; Memoria Histórica, 2011). Last, we observe that the effects on birth weight and height are primarily concentrated among married women or those in consensual unions, which may be explained by the heightened stress experienced by women with a partner during violent events that endanger their partner's life—an occurrence frequently observed in the Colombian conflict.[3]

Our research makes significant contributions to the existing literature in two ways. Firstly, unlike previous studies that focused on the effects of terrorism and non-state military operations (Brown, 2020; Camacho, 2008; Foureaux Koppensteiner & Manacorda, 2016; Mansour & Rees, 2012), we provide new evidence on the impacts of state-led military operations in urban environments. This innovative approach broadens our understanding of military interventions. Secondly, our study extends the analysis of the effects of the Colombian internal armed conflict (Angrist & Kugler, 2008; Camacho, 2008; Camacho & Rodriguez, 2013; Dube & Vargas, 2013; Vargas, 2012) on early life shocks, exploring a scale and scope that has not been previously addressed. Specifically, our paper investigates the influence of state military operations on infants' health outcomes (Camacho, 2008; Duque, 2017; Kreif et al., 2022; Rodríguez, 2022), providing the first empirical evidence of the effects in impoverished urban areas. Our results shed light on potential negative consequences of state-led military operations, which could assist in improving their design to mitigate adverse effects on the population's well-being in different contexts.

The remainder of this paper is organized as follows. Section 2 provides institutional context, situating Operation Orion within the broader context of military intervention in urban settings. Section 3 describes the data sources and provides descriptive statistics, summarizing the key features of the data and highlighting any relevant limitations. Section 4 describes the identification strategy, outlining the analysis' key assumptions and discussing the potential for bias. Section 5 presents the main findings, providing estimates of the effect of Operation Orion on birth outcomes. Sections 6 and 7 provide the final discussion and conclusions.

2. Institutional context

2.1. Colombian internal conflict

Colombia was one of the countries most affected by violence during the second half of the 20th century. The internal conflict started in the mid-1960s with the foundation of the left-wing guerrilla groups Revolutionary Armed Forces of Colombia (FARC, its Spanish acronym) and the National Liberation Army (ELN, its Spanish acronym), which were located mainly in rural areas and came to control an important part of the country's territory. Indeed, as a military strategy, the guerrillas sought to populate areas with a remarkable absence of the state, thus achieving the control of a consolidated location that increases their ability to expand and extract rents through crime (Aricapa, 2017). As a result, the internal conflict that lasted over fifty years has left more than a million homicides and around 8.4 million displaced.[4]

Initially, the conflict mainly concentrated in rural areas; however, some guerrillas started locating small cells in the main cities. That was the case of Medellin. Guerrilla groups took advantage of the fact that the most violent neighborhoods were growing rapidly but with high levels of inequality, poverty, and a lack of government authority. In particular, ELN and FARC targeted the north and west of the city in *Comuna 13* or *San Javier*, and *Comuna 1* or *Popular*, whose neighborhoods are known to be among the poorest in the city. Thereby, in the mid-1990s, the ELN coordinated the land invasion of *El Salado*, a neighborhood between *San Javier* and the rural area of *San Cristobal* in the western part of the city, where they illegally offered plots of land and construction materials to displaced individuals from the pacific coast of Colombia (Memoria Histórica, 2011). Simultaneously, several independent militias also exercised control over the people and territory, assigning land plots and distributing food and goods from the assault of transporting vehicles. In addition, the FARC militias were also present towards the end of the 1990s, consolidating *Comuna 13* as one of the areas with the highest risk and difficulty to control for the local and national governments.

The conflict escalated in 1997 when several militias of the right-wing paramilitary group[5] *Autodefensas Unidas de Colombia* (AUC) tried establishing territorial control in *Comuna 13*. By 2002, the situation worsened because the left-wing militias prohibited neighbors outside *Comuna 13* from entering, held checkpoints on buses, and paralyzed schools. Consequently, public transport in several areas of *Comuna 13* was interrupted, and some local businesses closed.

To counteract the situation, the AUC engaged in violent confrontations through a series of military interventions across different neighborhoods of *Comuna 13*. The most critical moment occurred on May 31, when the mayor of Medellin, Luis Pérez Gutierrez, inaugurated the new bus terminal in *San Javier*. The FARC attacked the bus that transported the mayor, and although he was not hurt, this attack triggered several measures to regain control of the area. First, the Police started constructing a new military base in *Comuna 13*, reinforcing their presence with 300 police officers equipped with specialized gear and weapons and a 500 million Colombian Pesos fund to pay informants (Aricapa, 2017). Second, in August 2002, after the presidential inauguration of Alvaro Uribe, the mayor, Luis Pérez, requested intervention from the national government. Finally, in October 2002, the military and police authorities planned a decisive move: Operation Orion.

2.2. Operation orion

Operation Orion was the largest and most dramatic urban military operation at Colombia's urban level (Aricapa, 2017). As Montoya (2021) described, at midnight on October 16, 2002, the government mobilized 1500 men from the army and police. Armed with sophisticated weapons, they arrived in military vehicles at the edge of the *Comuna 13*. According to the declarations of several paramilitary leaders, the operation was accompanied by paramilitary members who had previously carried out intelligence work (Memoria Histórica, 2011).

From then on, the men from the Special Counterterrorism Command started walking up into the target area, starting with the neighborhood of *San Javier*. The objective was to take control of this geographical area of the city controlled by the militiamen, mainly members of the left-wing guerrilla group ELN. The foray into the neighborhood was violent and generated fear among the inhabitants. From the start of the operation, the electric power was cut off. Then, two helicopters entered, lifting the roofs of some houses, and the exchange of high-caliber firearms (even those used for war in rural areas) began between the advancing official forces and the presence of paramilitaries in the upper neighborhoods, resulting in a grim toll of 100 fatalities, 300 injuries, and around 500 missing persons (Memoria Histórica, 2011).

In the early morning, the war tanks entered, continuing the shooting and the back and forth of grenades. This was how the inhabitants of the

[3] The disproportionate impact of violent conflict in Colombia on men is evident from the fact that 92 percent of conflict-related deaths occur among males (CNMH, 2023).

[4] Statistics retrieved from *Registro Único de Víctimas*, https://www.unidadvictimas.gov.co/es/registro-unico-de-victimas-ruv/37394, accessed April 15, 2023.

[5] According to the Cambridge Academic Content Dictionary, "*a paramilitary group is organized like an army but is not official and often not legal*", https://dictionary.cambridge.org/us/dictionary/english/paramilitary, accessed August 17, 2023.

Comuna 13 and the militiamen (some of them recruited teenagers) were trapped between the official forces coming up and the paramilitaries in the upper neighborhoods. The dead were accumulating, and some bodies were never found. According to interviews and testimonies, Operation Orion inflicted intense psychological pressure on the inhabitants who lived in the affected areas (Aricapa, 2017). Memoria Histórica (2011) said that Operation Orion remained in the memory of the inhabitants of *Comuna 13* as the day when the war entered "the bowels of their homes," and according to Yagoub (2017), this operation exposed the locals to extreme violence, while essentially replacing the guerrillas problem with another.

In the Operation, the "informants" were vital. They were protected by military vehicles, although they wore bulletproof vests like the official forces. These people would be safe until the authorities took over the territory. Most of these informants were militiamen in the past. However, the payment offered by the right-wing paramilitary groups was higher than what they were receiving, and they changed sides (Montoya, 2021).

The Informants were accompanied by officials from the Prosecutor's Office, who, with a list of names of militiamen and collaborators, went from house to house looking for these people. The public force was responsible for entering the interior of the designated houses and exhaustively searching for subversives, hostages, arms, contraband, and illicit substances, which implied high stress for the inhabitants of the houses. The residents of these neighborhoods protected themselves from stray bullets, explosions, or violence upon entry of the home inspection, under beds, and by putting mattresses, cardboard, or other materials on windows, doors, and walls (Montoya, 2021).

The official authorities' statement, according to Montoya (2021), is not entirely accurate in the sense that they said that the successful Operation Orion of 2002 was carried out by the state public force (military and police), concealing that it was in turn, a result of an alliance with the paramilitaries. Outside the law, these criminal groups of right-wing political orientation committed multiple human rights violations and exercised disappearances, extrajudicial executions, and forced population displacement. According to several authors, the operation was not a victory for the State but a defeat for the population of the *Comuna 13*, who faced the consequences of the indiscriminate violence of the official forces and the paramilitaries.

Although there is no consensus about the duration of the operation, most sources stated that it lasted around one week between October 16 and 23. We use the investigation report of Memoria Histórica (2011) to define the neighborhoods where Operation Orion took place. *Comuna 13* had 19 neighborhoods by 2002. Six of those were intervened: *Belencito, Corazón, 20 de Julio, El Salado, Nuevos Conquistadores, and Las Independencias*.[6] This information and the operation's dates allow us to build a repeated cross-section of births in Medellin from 2002 to 2003.

3. Data

3.1. Birth records

Our primary source of information is the VSR collected by Colombia's Administrative Department of Statistics (DANE, for its Spanish acronym). VSR has data about the specific date and hospital where each woman gave birth and about the newborn, such as sex, weight, height, and APGAR score. It also includes some variables with information about the mothers, such as department and municipality of residence, age, educational attainment, type of health insurance, marital status, number of children, and number of pregnancies. Specifically, VSR allows us to identify the neighborhood where each mother is located.

We focused on birth certificates in Medellin from 2002 to 2003 to consider the cohort right before and potentially exposed to the intervention.[7] The key variables for identifying the mothers affected by the operation are birth date, gestational length (weeks), and the neighborhood of residence.

All birth certificates include the first two variables, which we used to build the date of conception. However, although the birth certificates for 2003 were supposed to have the neighborhood of residence, they were only reported between May and August 2003. Therefore, for that year, we can only observe the residence neighborhood of mothers who gave birth in those months. Given such constraints, we cannot estimate the effect on newborns exposed during the second trimester. Nonetheless, we can estimate the effects for the first trimester. We define the first trimester for the treatment group as newborns whose period between conception and the 12th week of pregnancy overlaps with Operation Orion and who were born between May and July 2003. Notice that this definition (given data limitations) does not include newborns born in April 2003.[8] For the pre-treatment period, we include the same constraints and definitions. Similarly, we restricted the sample to newborns in the third trimester to those born up to December 2002.

Then, we used two different samples for newborns exposed in the first and the third trimesters because previous literature evidences the importance of exposure time.[9] Our principal analysis focuses on mothers affected by Operation Orion in their pregnancy's first trimester since previous evidence shows it is where the effect of violence on birth outcomes concentrates (Brown, 2018; Camacho, 2008; Dagnelie et al., 2018; Le & Nguyen, 2020; Mansour & Rees, 2012; Quintana-Domeque & Ródenas-Serrano, 2017). Nonetheless, we also show the results in the appendix using newborns exposed during the third trimester (See Table A.1).

To provide additional evidence on the validity of our estimations, we used VSR from 2000 to 2001 to run a placebo test with a fake intervention date, October 16th, 2000, two years before Operation Orion. For these years, as gestational length is not available in weeks but in intervals, we cannot precisely determine the mothers possibly exposed to the placebo. However, we can approximate them using Foureaux Koppensteiner and Manacorda (2016)'s approach, where intervals are converted into average gestational length in weeks using gestation in weeks available in the 2002 and 2003 birth data. Specifically, we use the average weeks observed in 2002–2003 data.[10]

3.1.1. Outcomes

VSR allows the measurement of several outcomes: birth weight, birth height, prematurity, APGAR score, and SGA. Birth weight has been one of the key health measures at birth studied in the literature (Currie, 2011). Birth weight –notably, low birth weight– is highly correlated with mortality (Almond, Chay, & Lee, 2005; Gonzalez & Gilleskie, 2017; World Health Organization, 2016). Low birth weight is defined as being born with a birth weight below 2500 g. Instead of focusing on a binary outcome such as low birth weight, in the results

[6] See Fig. A.1 where these neighborhoods are presented in dark gray, the rest of the *Comuna 13* are in light gray, and the rest of the districts of Medellin are in white.

[7] We have access to all fetal death reports, which, in principle, would allow us to estimate the effects on fetus mortality. Although the death certificate includes information on the exact date of the death, it does not provide information on the neighborhood of residence. Given this constraint, we cannot define the treatment of all potential pregnancies.

[8] Depending on the gestational length, most newborns born in April 2003 were conceived before Operation Orion and possibly exposed to it. Still, due to a lack of data on the neighborhood of residence, we did not include them in our analysis.

[9] See, e.g., Camacho (2008), Foureaux Koppensteiner and Manacorda (2016) and Mansour and Rees (2012) and others.

[10] We run a similar exercise using the minimum gestational length in each interval to calculate the gestational length and find similar results.

section, we estimate UQR (Firpo et al., 2009) for a wide variety of values on the birth weight distribution, including 2500 g.

Height or birth length is an important indicator of individuals' health (Christian, 2022; Raghavan et al., 2022). Birth length strongly predicts later growth and can signal stunting at a very early stage of life (Krebs et al., 2022). In addition, older children with short stature tend to have language scores approximately a quarter of a standard deviation lower than those with typical height. Short stature also predicts inferior language development (Freer et al., 2022). Children with short stature are likelier to belong to the lowest-performing group and less likely to be associated with the high-score group (Freer et al., 2022).

Both prematurity and SGA are highly correlated with infant mortality and morbidity. For instance, prematurity is one of the leading causes of childhood deaths globally (Liu et al., 2012) and is associated with several long-term medical conditions such as cerebral palsy and impairments (Moster, Lie, & Markestad, 2008; Ream & Lehwald, 2018). Likewise, SGA is also related to short- and long-term increased risks, including motor and sensory neuro-developmental deficits, cognitive and learning impairments, cerebral palsy, metabolic consequences, and cardiovascular disease (Fung & Zinkhan, 2021).

The APGAR score is a widely-used indicator in the literature for assessing the health status of newborns (Almond, Doyle, Kowalski, & Williams, 2010; Lin, 2009). This score is based on observable health indicators of the newborn one minute after birth, including breathing, heart rate, color, reflexes, and muscle tone. Each indicator receives 0, 1, or 2 points, resulting in an APGAR score ranging from zero to ten (Moore et al., 2014). Originally designed to assess a newborn's immediate condition and adjustment to life outside the womb, the APGAR score strongly predicts infant mortality and offers practical advantages (Almond et al., 2005). Notably, it is easy to collect, readily available in administrative data, and does not depend on rare events like mortality. Our empirical analysis uses an indicator variable to identify newborns with an APGAR score of 7 or higher, representing good health at birth.

3.2. Main sample

We identified infants in the first trimester of pregnancy when Operation Orion occurred that had complete information on the key variables for the design, resulting in 4345 birth registries. These newborns make up the post-treatment sample. We used the same dates and definitions for the previous year to identify the pre-treatment sample, resulting in 4509 observations. The final data set has 8854 observations (birth registries) classified into treated (272) or control (8582) according to the area of residence reported in the hospital by their mothers. We are aware of the small number of treated clusters in our sample, so we used the wild bootstrap approach proposed by MacKinnon and Webb (2019) and the randomization inference method developed by MacKinnon and Webb (2020) to account for that potential problem and check the robustness of our results.

We present results for newborns affected in the first trimester since previous evidence has shown that the effects concentrate on that stage of pregnancy (see, for example, Mansour & Rees, 2012 or Camacho, 2008) and because of data limitations mentioned in the previous section.

Table 1 presents the summary statistics of our main sample. As shown in the table, infants weigh, on average, 3111 g, with a standard deviation of 440 g. Infants have an average height of 49.2 cm, with a standard deviation of 2.3 cm. 94% of the births had an APGAR score of seven or more. Concerning the socioeconomic variables, 25.7% of the deliveries are from mothers with primary or lower educational attainment, around 70% are from married mothers or mothers in a consensual union, and the average age of the mothers is 25.4 years old (standard deviation of 6.8 years). Finally, around 49% of births were born in the post-treatment period,[11] and 3.1% were from mothers living in neighborhoods affected by Operation Orion.

Table 1
Descriptive statistics for key variables.
Source: Authors' calculations based on VSR.

	(1) Mean	(2) S.D.
Birth Outcomes		
Birthweight	3,110.754	440.161
Height	49.244	2.333
Gestational length (weeks)	38.948	1.358
Premature	0.047	0.211
APGAR 1 min ≥ 7	0.940	0.237
APGAR 1 min 5 or 6	0.031	0.173
APGAR 1 min < 5	0.013	0.112
Birth and pregnancy characteristics		
Born in the post-treatment period	0.491	0.500
Born on a treated neighborhood	0.031	0.173
Prenatal visits	5.459	2.351
Female	0.490	0.500
Number of pregnancies	2.212	1.505
Number of previously born alive	2.017	1.313
Mother and Father characteristics		
Mother's age	25.420	6.767
Father's age	29.288	7.823
Mother's educational attainment		
None	0.036	0.186
Incomplete primary	0.099	0.299
Complete primary	0.122	0.328
Incomplete secondary	0.325	0.468
Complete secondary	0.290	0.454
Incomplete tertiary	0.048	0.213
Complete tertiary	0.080	0.271
Mother's type of insurance		
Contributory regime	0.491	0.500
Subsidised regime	0.208	0.406
Connected population	0.221	0.415
Special regimes or other	0.080	0.271
Mother's marital status		
Single	0.269	0.443
Married	0.285	0.452
Widow or divorced	0.030	0.171
Consensual union	0.416	0.493
Neighborhoods	240	
Observations	8854	

Notes: This table presents summary statistics for the outcomes and covariates of birth for our main sample (first trimester). Premature is a dummy that takes the value of one if the gestational length is lower than 37 weeks.

4. Empirical strategy

To identify the causal effect of Operation Orion on birth outcomes, we exploit the timing of the operation and the neighborhood variation where the intervention occurred. Specifically, we exploit Operation Orion's timing, which started on October 16, 2002, and lasted one week, and the differential exposure to violence associated with the operation among neighborhoods in *Comuna 13* and the rest of Medellin.

We start by identifying all the births of pregnant women affected by Operation Orion in their first trimester of gestation by calculating conception dates using birth dates and gestational age.[12] The deliveries potentially exposed to the intervention were born between May 1, 2003, and July 30, 2003. We defined this sample as the cohort born after the operation. Second, we identify all the births born on the

[11] Newborns whose conception date was before and birth date was after Operation Orion.

[12] Following Quintana-Domeque and Ródenas-Serrano (2017), we use gestational age minus two as conception usually occurs two weeks after the last standard menstrual period (definition of gestational age).

same dates but one year before, i.e., those born between May 1, 2002, and July 30, 2002, who were not exposed to the operation. We defined this sample as the cohort before the operation. Finally, we identified the neighborhood where the mothers lived at the moment of the intervention, and we defined treated neighborhoods as those where Operation Orion took place. Control neighborhoods are all other neighborhoods in Medellin. We estimate a standard DiD regression:

$$Y_{int} = \alpha_0 + \alpha_1 Orion_n + \alpha_2 Post_t + \beta Orion_n \times Post_t + \theta X_{it} + \varepsilon_{int} \quad (1)$$

Where Y_{int} is the outcome of the child i from neighborhood n at time t, $Orion_n$ shows whether the neighborhood n was affected by Operation Orion, and $Post_t$ takes the value of one for the cohort born after the operation and zero otherwise. X_i includes a set of covariates such as the mother's educational attainment, marital status, type of health insurance, mother's age, mother's number of previous pregnancies and alive children, and newborn's sex. Finally, the error term is ε_{int}. We cluster standard errors at the neighborhood level in all our exercises (unless otherwise stated).

Our coefficient of interest, β, captures the differential change in the birth outcome before and after Operation Orion in neighborhoods exposed to Orion versus those not exposed to the operation. The main identifying assumption behind our DiD strategy is parallel trends, which assumes that in the absence of Operation Orion, the average birth outcome in neighborhoods exposed to the intervention would have evolved similarly to those in neighborhoods non-exposed to the intervention.

Including covariates in our DiD design implicitly assumes that parallel trends hold conditional on such covariates and that there are no heterogeneous treatment effects (Sant'Anna & Zhao, 2020). We implement the DR estimators for the DiD research designs proposed by Sant'Anna and Zhao (2020) to take advantage of including covariates without imposing additional assumptions. The DR estimator combines the regression approach and re-weighting procedure and is consistent if the propensity score associated with the re-weighting procedure or the outcome regression models are correctly specified.

Besides, we test whether Operation Orion affected mostly births at the bottom of the distribution (e.g., low birth weight) or if, on the contrary, the results are concentrated in the median part of the distribution. These effects are usually associated with the weakest live-born fetuses in the population. To do that, we implement the Unconditional Quantile Regression proposed by Firpo et al. (2009). The specification is:

$$RIF(y_{int}; q_\tau, F_y) = \alpha_0 + \alpha_1 Orion_n + \alpha_2 Post_t + \beta Orion_n \times Post_t + \theta X_i + \varepsilon_{int} \quad (2)$$

where q_τ denotes the τth percentile of the outcome, F_y represents the marginal (unconditional) distribution, and the re-centered influence function (RIF) is defined:

$$RIF(y_{int}; q_\tau, F_y) = q_\tau + \frac{\tau - \mathbb{1}\{y_{int} < q_\tau\}}{f_y(q_\tau)} \quad (3)$$

Finally, we examine heterogeneous effects across different pre-treatment demographic and socioeconomic characteristics by estimating the effects over specific sub-samples, such as female newborns or children from less educated mothers.

5. Results

This section presents the main results in the following order. In Section 5.1, we show the main effects of Operation Orion on birth outcomes and prenatal visits using both standard DiD and the (Sant'Anna & Zhao, 2020) DR method. Then, in Section 5.2, we investigate the possibility of heterogeneous treatment effects across the distribution of newborn health outcomes. To this end, we employ the UQR approach (Firpo et al., 2009). In Section 5.3, we explore whether Operation Orion's effects are more pronounced among some subgroups.

Finally, in Section 5.4, we address concerns about biases associated with changes in the composition of treated women and perform several robustness checks. For instance, we conducted a falsification test that assumes the intervention occurred two years before the actual date and a permutation test in which we randomly allocated the treatment to different neighborhoods 1000 times.

5.1. Main results

Table 2 reports the effect of Operation Orion on several outcomes using two specifications: the DiD estimator of Eq. (1), and the improved DR DiD estimator (Sant'Anna & Zhao, 2020). We focus on the number of prenatal care visits and birth outcomes: birth weight, birth height, the probability of a baby born before 37 weeks of pregnancy (premature), the likelihood of having an APGAR score higher than seven, and the probability of being small for gestational age –defined as birth weight below the 10th percentile for gestational age–. We find that Operation Orion negatively and significantly affects birth weight and height and the likelihood of having an APGAR score above 7.

Results suggest that infants born in treated neighborhoods and exposed to the intervention during the first trimester of pregnancy weight, on average, 116.5 g less than the rest of the births, corresponding to a significant reduction of 3.75% in the average baseline weight (3106 g) or a 0.27 standard deviation decrease, based on the DR specification of column (2). Similarly, we find that children born in a treated neighborhood exposed to the intervention have an average height of 0.51 cm lower than the rest of the births –column (4)–. This effect corresponds to a reduction of 1% in the average baseline height (49.3 cm). Also, we observe a decrease of 3 percent in the probability of being born with an APGAR score above 7, representing a relative effect of 3.26% –column (8)–. These results are robust to the different specifications, including two-way fixed effects (see Table A.2 in the appendix) and other ways to estimate the standard errors, particularly the wild bootstrap approach proposed by MacKinnon and Webb (2019).

Operation Orion was conducted after a long absence of state and urban armed conflict. This scenario led to fear and stress in *Comuna 13*'s population, especially in pregnant women, causing reductions in birth weight and other outcomes similar to the effects of previous studies. For instance, for Colombia, Camacho (2008) found a significant decrease of 0.24% in birth weight (7.7 g relative to an average of 3153 g) for children born in a municipality with landmine explosions during early pregnancy. For Palestine, Mansour and Rees (2012) found that exposure to the average conflict-related casualties increased the probability of low birth weight by 18.4% (2.2 pp relative to a baseline probability of 12 pp). For Spain, Quintana-Domeque and Ródenas-Serrano (2017) found that the Hipercor bombing terrorist attack of 1987 significantly reduced birth weight by 11.5 g in the first-trimester pregnancy, representing a decrease of 0.35% in the baseline average birth weight.

Our results also align with de Oliveira, Lee, and Quintana-Domeque (2021) and Torche (2011) for natural disasters. For example, Torche (2011) found a significant reduction of 51 grams because of a major earthquake in Chile, while de Oliveira et al. (2021) found that newborns exposed to Hurricane Catarina experienced an average reduction of 44 g in birth weight, representing −0.09 standard deviations or −1.34% effect of the pre-hurricane average birth weight.

The military operation has enforced a mandatory lockdown on the people in the area, which could potentially affect their access to healthcare and nutrition, which in turn may harm infants' well-being due to insufficient food (Abu-Saad & Fraser, 2010; Alexander & Korenbrot, 1995) or poor quality of the food and environment that mothers are exposed to.[13]

[13] For example, Arnetz, Drutchas, Sokol, Kruger, and Jamil (2013) find a negative relationship between chemical and non-chemical factors in the

Table 2
Birth outcomes and Operation Orion.

Dependent variable	Birth weight		Birth height		Premature	
	(1) DiD	(2) DR	(3) DiD	(4) DR	(5) DiD	(6) DR
Orion	−90.32**	−116.53***	−0.53**	−0.51**	−0.0189	0.0004
	(39.39)	(41.80)	(0.24)	(0.21)	(0.0306)	(0.0267)
Wild-bootstrap 95% C.I.	[−215.1, −8.8]	[−198.5, −34.5]	[−1.19, 0.28]	[−0.96, −0.07]	[−0.09, 0.05]	[−0.06, 0.06]
Observations	8,854	8,854	8,854	8,854	8,854	8,854
Neighborhoods	240	240	240	240	240	240
Mean DV	3,105.91	3,105.91	49.30	49.30	0.04	0.04
SD DV	430.15	430.15	2.23	2.23	0.20	0.20

Dependent variable	APGAR 1 min ≥ 7		Small for Gestational Age		Prenatal Visits	
	(7) DiD	(8) DR	(9) DiD	(10) DR	(11) DiD	(12) DR
Orion	−0.03**	−0.03***	−0.0001	0.0006	−0.09	−0.22
	(0.01)	(0.01)	(0.0021)	(0.0027)	(0.30)	(0.25)
Wild-bootstrap 95% C.I.	[−0.069, 0.002]	[−0.052, −0.014]	[−0.005, 0.005]	[−0.004, 0.006]	[−0.93, 0.55]	[−0.76, 0.31]
Observations	8,854	8,854	8,854	8,854	7,958	7,958
Neighborhoods	240	240	240	240	238	238
Mean DV	0.92	0.92	0.01	0.01	5.42	5.42
SD DV	0.27	0.27	0.10	0.10	2.38	2.38

Notes: This table presents the results from regressions with birth weight, height, prematurity, APGAR 1 min greater or equal to seven, small for gestational age, and prenatal visits as the dependent variables using data from 2002 to 2003. Orion is a dummy that takes the value of one for treated neighborhoods after exposure to the intervention. Columns (1), (3), (5), (7), (9), and (11) estimate the DiD estimator using equation (1), and columns (2), (4), (6), (8), (10), and (12) estimate the Sant'Anna and Zhao (2020)'s Improved DR DiD estimator. All columns include the following controls: mother's and father's age, dummies for the type of insurance, dummies for the mother's educational attainment, dummies for the mother's marital status, number of previously born alive, number of pregnancies, and whether the newborn is female. Robust standard errors clustered by neighborhood are reported in parentheses. 95% confidence intervals (C.I.) using wild cluster bootstrap with 1000 replications reported in brackets. Significance levels according to t-statistic: 1% ***, 5% **, 10% *.

Prematurity and SGA are usually associated, among other factors, with fetal growth restriction resulting from inadequate nutrient and oxygen supply during pregnancy (Naaz & Muneshwar, 2023; Slyker et al., 2014; Villar et al., 2014).[14] Our analysis reveals that Operation Orion has no significant effect on these indicators. We also test the effects on prenatal appointments. Although for only a short period, the compulsory lockdown may also limit medical guidance and supervision. As expected, our analysis reveals that Operation Orion does not significantly impact the number of prenatal visits, which serve as a proxy for prenatal medical care access.

5.2. Heterogeneous effects across the distribution of newborn health outcome

Table 3 presents the UQR or RIF regression for the birth weight and height percentiles, using Eq. (2). The findings suggest no statistically significant effects on the bottom and top of the birth weight and height distributions. In general, these results are associated with less precisely estimated coefficients. Nonetheless, the effects are statistically significant for newborns around the median weight (3100 g) and between the 25th and 50th percentile for height, as illustrated in Fig. A.2 in the appendix.

5.3. Heterogeneous effects across demographic and socioeconomic characteristics

Our study includes several heterogeneous exercises with pre-treatment controls. To this end, we stratify the sample by newborns' sex, maternal age (adult vs. teenage mothers), type of health insurance, educational level (secondary or higher vs. primary or lower), and marital status (married or in consensual union vs. other), to examine how the treatment effect varies across different characteristics. We estimate the DR method in all cases and use wild-bootstrap with 1000 replications. Our results are robust to the DiD method and the method of standard error estimation.

Figs. 1(a), 1(b), and 1(c) present the results of our heterogeneity analysis of the impacts of Operation Orion on birth weight, height, and the probability of an APGAR score greater than 7, respectively. While the estimated coefficient is negative overall, it is not statistically significant for some groups. In addition, we find no statistically significant differences within groups except for three cases. First, we observe that the effects on birth weight and height are concentrated among mothers who are married or in a consensual union. However, the difference concerning mothers with other marital statuses is only significant for birth weight. This result may be explained by the fact that women with a partner are more likely to experience stress during violent events that endanger their partner's life, a common occurrence during the Colombian conflict. Second, the effects on birth weight are more pronounced for newborns whose mothers have primary or lower levels of education. Third, the effects on the probability of APGAR scores higher than seven are concentrated among adult mothers rather than teenage mothers and among male newborns rather than female newborns. Our results are robust to the DR method with wild-bootstrap standard errors. They are not sensitive to the choice of the DiD method or the method used to estimate the standard errors.

5.4. Additional tests

In this section, we aim to address potential concerns regarding identification issues. First, we examine the possibility of a composition effect among treated women. A critical concern is that Operation Orion may affect the number of newborns through intra-urban migration or fetal mortality, leading to a bias associated with changes in the composition of treated women. To test this hypothesis, we use a

environment of the mothers that experienced the Gulf War and adverse birth outcomes, and Hobel et al. (2008) explain that the nutrition of the mothers' directly affects the nutrition of the fetuses which subsequently can result on insufficient fetal growth.

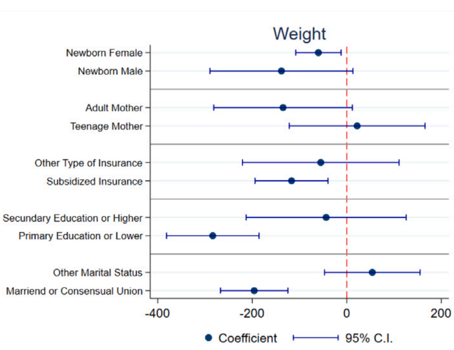
[14] Literature also shows association with stress and others, see for example, Hobel et al. (2008), Loomans et al. (2013) and Traylor et al. (2020).

Table 3
Unconditional Quantile Regression: Birth Outcomes and Operation Orion.

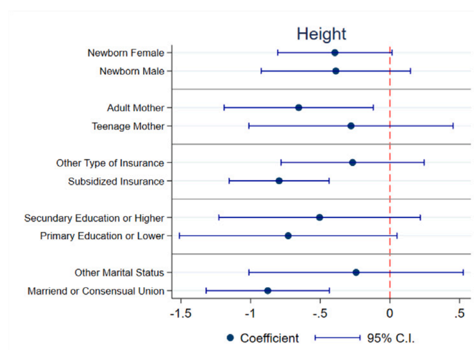
Percentile	P10	P25	P50	P75	P90
Dependent variable	Birth Weight				
	(1)	(2)	(3)	(4)	(5)
Orion	−29.71	−26.52	−121.55***	−81.18	−127.09
	(64.09)	(44.68)	(33.57)	(72.04)	(111.82)
Conventional 95% C.I.	[−156.0, 96.5]	[−114.5, 61.5]	[−187.7, −55.4]	[−223.1, 60.7]	[−347.4, 93.2]
Observations	8854	8854	8854	8854	8854
Sample mean RIF	2,572.4	2,821.2	3,135.6	3,414.3	3,653.6
Neighborhoods	240	240	240	240	240
Mean DV	3,105.91	3,105.91	3,105.91	3,105.91	3,105.91
SD DV	430.15	430.15	430.15	430.15	430.15
Dependent variable	Birth Height				
	(6)	(7)	(8)	(9)	(10)
Orion	−0.25	−0.55***	−0.50**	−0.21	−0.45
	(0.19)	(0.18)	(0.22)	(0.46)	(0.44)
Conventional 95% C.I.	[−0.62, 0.12]	[−0.89, −0.20]	[−0.93, −0.07]	[−1.11, 0.70]	[−1.32, 0.43]
Observations	8854	8854	8854	8854	8854
Sample mean RIF	47.1	48.5	49.8	51.1	52.4
Neighborhoods	240	240	240	240	240
Mean DV	49.30	49.30	49.30	49.30	49.30
SD DV	2.23	2.23	2.23	2.23	2.23

Notes: This table presents the results from UQR (Firpo et al., 2009) for different percentiles with birth weight and height as the dependent variables using data from 2002 to 2003. Orion is a dummy that takes the value of one for treated neighborhoods after exposure to the intervention. All columns include the following controls: mother's and father's age, dummies for the type of insurance, dummies for mother's and father's educational attainment, dummies for mother's marital status, number of previously born alive, number of pregnancies, and whether the newborn if female. Robust standard errors clustered by neighborhood are reported in parentheses. 95% confidence interval reported in brackets. Significance levels according to *t*-statistic: 1% ***, 5% **, 10% *.

(a) Birth weight



(b) Birth height



(c) Pr. APGAR 1 minute ≥ 7

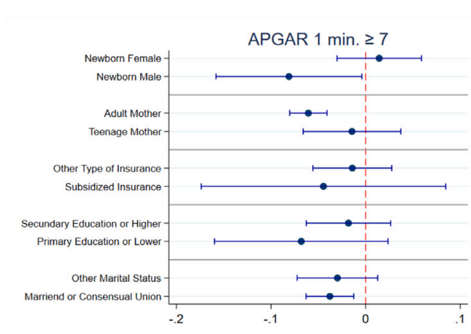


Fig. 1. Heterogeneous effects of operation orion on birth outcomes.
Notes: Figs. 1(a), 1(b), and 1(c) show estimated β coefficients from Eq. (1) based on Sant'Anna and Zhao (2020) DR estimation. Each estimated coefficient comes from a regression on the sub-sample specified on the vertical axis. See notes in Table 2 for further details.

neighborhood-month panel, which sums all the birth registries in the VSR in each neighborhood by month. We present the results in Table 4, demonstrating that the number of births by neighborhood did not change because of Operation Orion. Thus, evidence was provided that

Table 4
Number of newborns and Operation Orion.

Dependent variable	Number of newborns	
	(1) DiD	(2) DR
Orion	−1.91	9.52
	(1.67)	(6.61)
Wild-bootstrap 95% C.I.	[−5.1, 2.2]	[−4.0, 23.0]
Observations	1011	1011
Neighborhoods	240	240
Mean DV	8.77	8.77
SD DV	13.05	13.05

Notes: This table presents the results from regressions with the number of newborns per neighborhood as the dependent variables using data from 2002 to 2003. Orion is a dummy that takes the value of one for treated neighborhoods after exposure to the intervention. Column (1) estimates the DiD estimator using equation (1), and column (2) estimates the Sant'Anna and Zhao (2020)'s Improved DR DiD estimator. All columns include the following controls: average mother's and father's age, the share of mothers with each type of insurance, the share of mothers with each educational attainment, dummies for the birth month, and share of female newborns. Robust standard errors clustered by neighborhood are reported in parentheses. 95% confidence intervals (C.I.) using wild cluster bootstrap with 1000 replications reported in brackets. Significance levels according to *t*-statistic: 1% ***, 5% **, 10% *.

there was no change in the composition associated with the treatment units.

Second, we also conduct a falsification test that assumes the intervention occurred two years before the actual date. We assign "false treatment" to the corresponding newborns before Operation Orion. Then, using the birth registries from 2000 to 2001 instead of 2002 and 2003, we run Eq. (1) in the same conditions used for the primary sample. Here, we test whether this placebo treatment group for Operation Orion significantly impacts birth weight. If it does, then the impact must come from some underlying differences in trends between treated and control neighborhoods rather than from Orion. The results are shown in Table 5. We find that the placebo Operation Orion has no significant effect on birth weight, height, or the probability of having an APGAR greater than 7, suggesting that underlying differences in trends between treated and control neighborhoods do not drive our results.

Finally, a permutation test was carried out by randomly assigning the treatment to different neighborhoods 1000 times and then re-estimating using the DR specification on birth outcomes for each random assignment, providing an estimate of the probability that our coefficient of interest arises by chance. The distribution for estimated coefficients is displayed in Fig. 2. The results suggest that our estimated coefficients are below the 91st, 89th, and 81st percentiles of the resulting distribution of the effect of Operation Orion on birth weight, height, and the probability of a high APGAR score, respectively. On average, the evidence is insufficient to reject the null hypothesis that random exposure to the state military operation does not affect birth outcomes.

6. Discussion

In this section, we discuss how stress can be a channel through which Orion's operation affects birth outcomes. This urban military operation may have exacerbated stress levels in pregnant women, which is detrimental to fetal health and development. Extensive research shows that maternal stress during pregnancy is associated with reduced fetal growth and lower birth weight (Wadhwa et al., 1993), elevated stress hormone levels in the fetus (Glynn et al., 2001), cognitive and behavioral issues, increased susceptibility to obesity and metabolic disorders, and impaired immune function in offspring (Entringer et al., 2012). There is also a clear empirical link between maternal stress during pregnancy and low birth weight, among other outcomes (Davis et al., 2007). Literature in development economics also presents evidence that maternal stress is a primary mechanism through which conflict events impact maternal and fetal health (Spratlen et al., 2022).

According to Traylor et al. (2020), acute and chronic stress can induce allostatic overload, affecting the intricate interplay among maternal-placental-fetal endocrine and immune responses. These disturbances during pregnancy can heighten the risk of a spectrum of adverse pregnancy outcomes, including spontaneous preterm birth, preeclampsia, neonatal morbidity, and low birth weight. Similarly, Hobel et al. (2008) explain that maternal stress contributes to reduced fetal growth by two mechanisms: first, stress releases catecholamines, which limit the amount of substrate delivered to the fetus, and second, stress elevates maternal cortisol that leads to an excessive fetal exposition to glucocorticoids. Additionally, the paper by Loomans et al. (2013) analyzes different clusters of women characterized by stress and other characteristics. They found that babies born from women classified as 'high depression and high anxiety' had a significantly lower birth weight and size compared with babies from women in the 'low depression and low anxiety' cluster.

Based on findings concerning exposure to violence and socioeconomic strain, Arnetz et al. (2013) conclude that non-chemical environmental factors are associated with adverse birth outcomes. They employ a scale score encompassing congenital anomalies, stillbirth, low birth weight, and preterm delivery. The study reveals a heightened incidence of this scale among women exposed to the Gulf War in 1991 compared to those who had resettled from Iraq before the conflict began, thus emphasizing armed conflict as a significant risk factor for adverse birth outcomes.

In addition to the literature showing evidence on this link, we leverage information on the type of partner of the pregnant woman who suffered the event of violence to argue that some cases are likely to be more stressful than others. Section 5.3 revealed that the effects on birth weight and height primarily manifest among married women or those in a consensual union, which can be attributed to the heightened stress experienced by women with partners during violent events that endanger their loved ones' lives, as often observed in the context of the Colombian conflict (CNMH, 2023).

Finally, anecdotal evidence and testimonies point to the significant psychological pressure inflicted on the residents of *Comuna 13* during Operation Orion (Aricapa, 2017; Memoria Histórica, 2011). All together, these indicate that the main mechanism may be associated with maternal stress. In particular, the increased stress levels are a key plausible mechanism underlying the negative relationship between exposure to violence and birth weight.

7. Conclusion

In this paper, we examined the effects of the state's efforts to end the armed conflict with guerrillas in *Comuna 13* (Medellin, Colombia) in 2002 on newborns' birth outcomes. Our findings reveal that exposure to Operation Orion significantly reduced birth weights, height, and APGAR scores in the intervened neighborhoods compared to other areas. Specifically, neighborhoods that experienced Operation Orion exhibited an average birth weight reduction of 3.8% and a birth height reduction of 1% compared to non-intervened areas. Additionally, there was a 3.3% decrease in the probability of infants being born with an APGAR score greater than 7. This suggests that increased stress levels among pregnant women exposed to the operation likely contributed to the declines in birth weight and vitality. No significant effects were found on other health outcomes or prenatal visits, which the short duration of Operation Orion may explain.

One potential concern regarding our results is the possibility of migration biasing our estimated coefficients due to pregnant women moving to non-treated neighborhoods. However, we address this issue by showing that the number of births in each area remained unchanged following Operation Orion, providing evidence that migration did not affect our estimates.

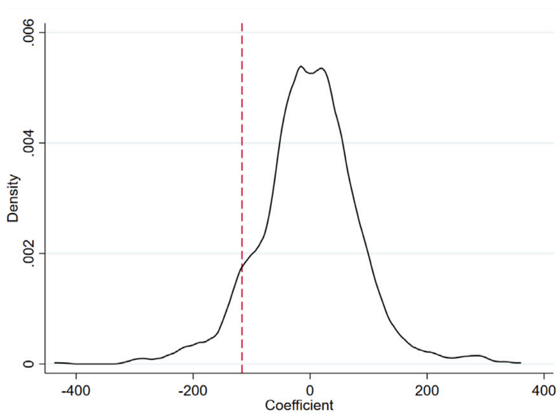
As documented in the literature, it is crucial to recognize that being born below-average weight and height has both short-term and

Table 5
Falsification test - Birth Outcomes and Operation Orion.

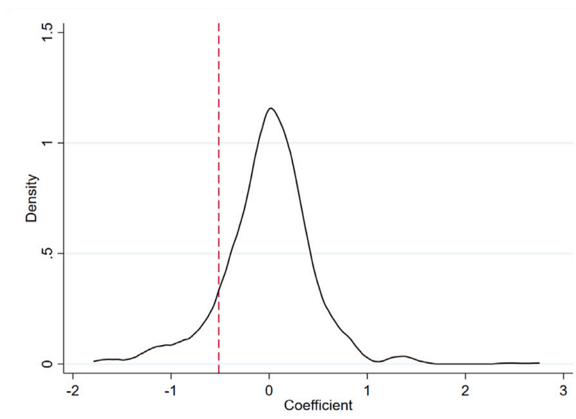
Dependent variable	Birth weight		Birth height		Apgar ≥ 7	
	(1) DiD	(2) DR	(3) DiD	(4) DR	(5) DiD	(6) DR
Orion	−23.88	−30.42	−0.34	−0.33	−0.009	−0.009
	(22.40)	(25.75)	(0.47)	(0.40)	(0.025)	(0.026)
Wild-bootstrap 95% C.I.	[−67.6, 46.8]	[−80.0, 19.1]	[−1.43, 1.24]	[−1.19, 0.52]	[−0.065, 0.053]	[−0.056, 0.038]
Observations	9669	9669	9669	9669	9669	9669
Neighborhoods	243	243	243	243	243	243
Mean DV	3,072.15	3,072.15	49.05	49.05	0.92	0.92
SD DV	500.12	500.12	2.67	2.67	0.28	0.28

Notes: This table presents the results from OLS regressions with birth weight, birth height, and APGAR score≥ 7 as the dependent variables using data from 2000 to 2001 and a fake intervention two years before the real one. See notes in Table 2 for further details. Data for 2000 and 2001 have the gestational length in intervals, so we computed it as the average weeks observed in 2002–2003 data. Robust standard errors clustered by neighborhood in parentheses. 95% confidence intervals (C.I.) using wild cluster bootstrap with 1000 replications reported in brackets. Significance levels according to *t*-statistic: 1% ***, 5% **, 10% *.

(a) Birth weight



(b) Birth height



(c) APGAR ≥ 7

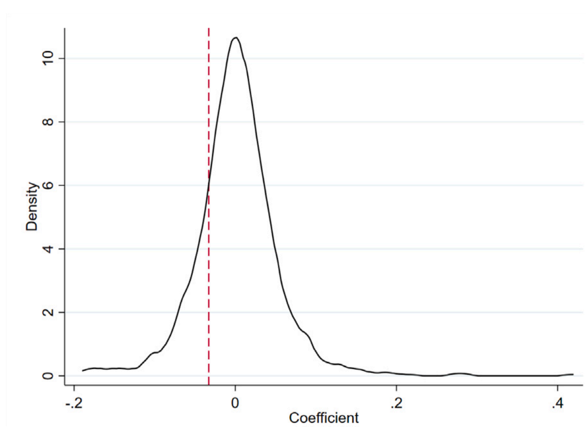


Fig. 2. Permutation test: Randomizing treated neighborhoods.
Notes: This figure presents the distribution of placebo treatments. We randomize the assignment of neighborhoods to have been exposed to Operation Orion based on the number of neighborhoods exposed (6). We run the regressions using the specification from Eq. (1) based on Sant'Anna and Zhao (2020) DR estimation from Columns 2, 4, and 6 in Table 2. Panels 2(a), 2(b), and 2(c) show the results for birth weight, height, and the probability of a high APGAR score, respectively. The red-dashed line presents the coefficient of Columns 2, 4, and 6 of Table 2 for Panels 2(a), 2(b), and 2(c), respectively. In Panel 2(a), the percent of cases where the placebo effects show a larger decrease in birth outcomes after the intervention is 0.085; in Panel 2(b), it is 0.109; and in Panel 2(c), it is 0.198.

long-term consequences. These consequences are associated with other health issues and lower academic performance, ultimately affecting upward social mobility.

In the case of Operation Orion, our findings underscore the importance of examining the unintended consequences of violent military interventions in urban areas. Our study highlights the substantial costs of the operation on children's health, revealing that the opportunity cost of such military interventions is more extensive than expected. Future state interventions should consider that exposure to violence resulting from confrontations with illegal armed groups has detrimental effects on birth weight and vitality. Thus, alternative intervention strategies that are less violent or non-military should be explored to mitigate these unintended consequences.

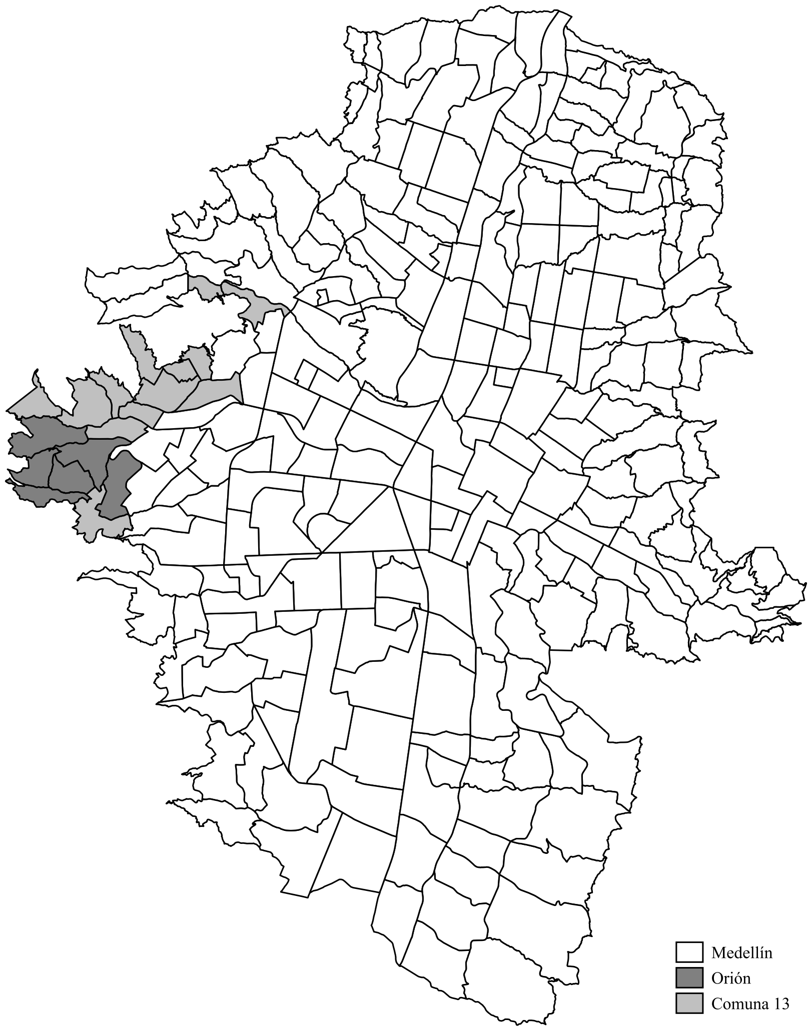


Fig. A.1. Medellin, Comuna 13, and Operation Orion.

In conclusion, it is important to emphasize the often-overlooked plight of pregnant mothers who endure moments of stress during times of war in a country. The focus is typically on immediately measurable damages such as casualties and material destruction. However, it is crucial to acknowledge the hidden, long-term consequences that affect the human capital of war-torn nations. In other words, some less visible victims bear severe implications of living in a war, and this article sheds light on the significance of pregnant mothers and unborn babies as part of these affected populations.

CRediT authorship contribution statement

Darwin Cortés: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Catalina Gómez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Conceptualization. **Christian Posso:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gabriel Suárez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Darwin Cortes reports financial support was provided by Colombian Ministry of Science, Technology, and Innovation (MINCIENCIAS). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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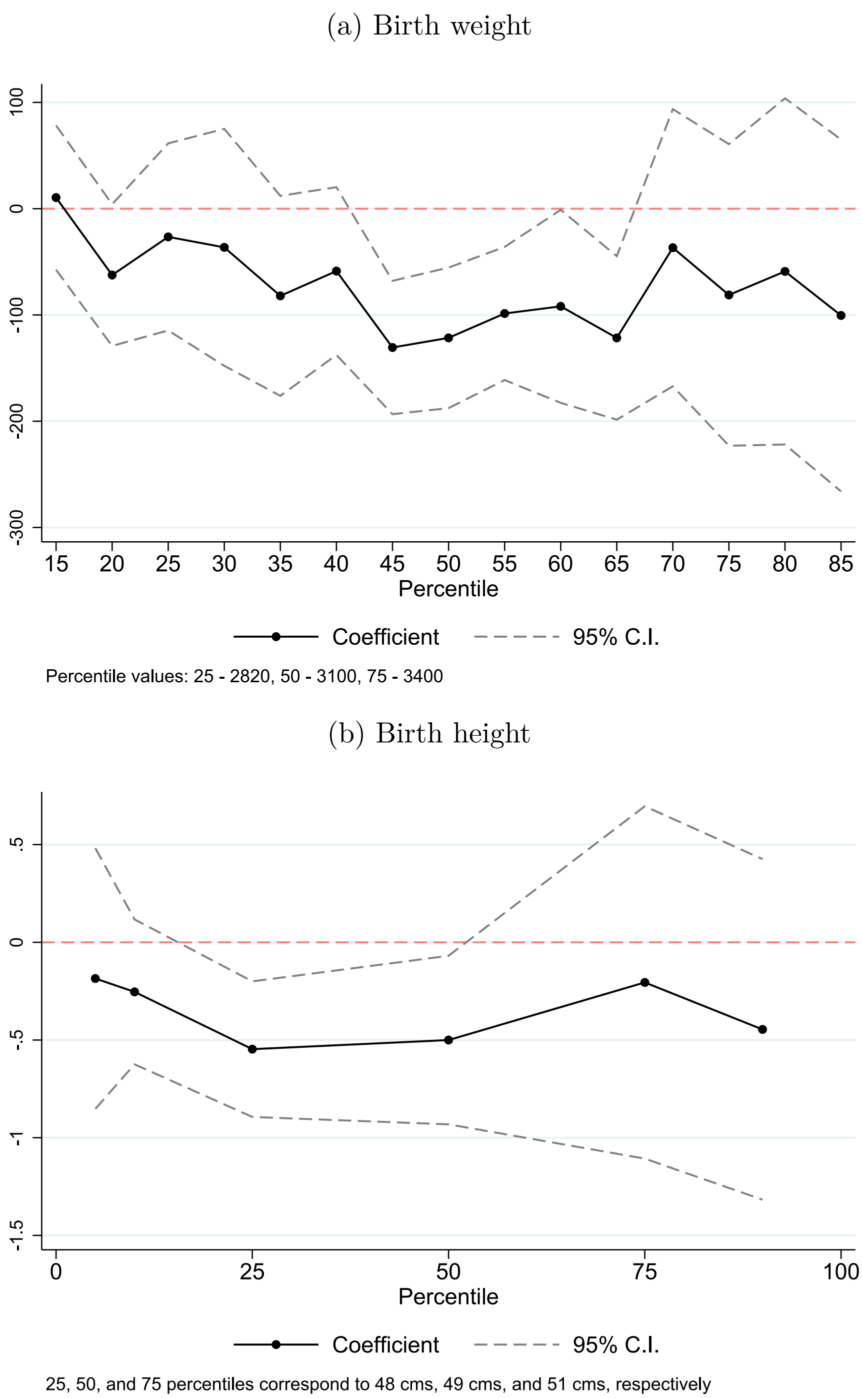

Fig. A.2. Unconditional quantile regression for birth outcomes.

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Appendix

See Figs. A.1, A.2 and Tables A.1, A.2.

Table A.1
Birth outcomes and Operation Orion - Third trimester.

Dependent variable	Birth weight		Birth height		Premature	
	(1)	(2)	(3)	(4)	(5)	(6)
	DiD	DR	DiD	DR	DiD	DR
Orion	13.28	2.55	−0.05	−0.12	−0.01	−0.02
	(62.37)	(63.18)	(0.14)	(0.15)	(0.02)	(0.02)
Wild-bootstrap 95% C.I.	[−153.2, 207.1]	[−120.2, 125.3]	[−0.33, 0.32]	[−0.41, 0.18]	[−0.06, 0.04]	[−0.06, 0.03]
Observations	9349	9349	9349	9349	9349	9349
Neighborhoods	241	241	241	241	241	241
Mean DV	3,107.33	3,107.33	49.08	49.08	0.13	0.13
SD DV	463.86	463.86	2.42	2.42	0.34	0.34

Dependent variable	APGAR 1 min ≥ 7		Prenatal Visits	
	(7)	(8)	(9)	(10)
	DiD	DR	DiD	DR
Orion	−0.01	−0.02	0.05	0.15
	(0.03)	(0.03)	(0.17)	(0.11)
Wild-bootstrap 95% C.I.	[−0.12, 0.06]	[−0.08, 0.04]	[−0.40, 0.38]	[−0.06, 0.36]
Observations	9349	9349	8032	8032
Neighborhoods	241	241	239	239
Mean DV	0.94	0.94	5.67	5.67
SD DV	0.25	0.25	2.55	2.55

Notes: This table presents the results from OLS regressions with birth weight, height, premature, Apgar 1 min greater or equal to seven, and number of prenatal visits as the dependent variables using data from 2001 to 2002 for newborns exposed during the third trimester of pregnancy. Small for Gestational Age is unavailable due to missing information on gestational age in weeks for 2001 data. Orion is a dummy that takes the value of one for treated neighborhoods after exposure to the intervention. Columns (1), (3), and (5) estimate the DiD estimator using equation (1), and columns (2), (4), and (6) estimate the Sant'Anna and Zhao (2020) Improved DR DiD estimator. All columns include the following controls: mother's and father's age, dummies for the type of insurance, dummies for the mother's educational attainment, dummies for the mother's marital status, number of previously born alive, number of pregnancies, and whether the newborn if female. Robust standard errors clustered by neighborhood are reported in parentheses. 95% confidence intervals (C.I.) using wild cluster bootstrap with 1000 replications reported in brackets. Significance levels according to t-statistic: 1% ***, 5% **, 10% *.

Table A.2
Birth outcomes and Operation Orion - TWFE estimates.

Dependent variable	Birth weight	Birth height	Preterm	APGAR 1 min ≥ 7	SGA	Prenatal visits
	(1)	(2)	(3)	(4)	(5)	(6)
Orion	−75.08**	−0.47*	−0.02	−0.02*	0.00	−0.13
	(31.97)	(0.25)	(0.03)	(0.01)	(0.00)	(0.30)
Wild-bootstrap 95% C.I.	[−165.3, −11.3]	[−1.09, 0.39]	[−0.09, 0.05]	[−0.05, 0.00]	[0.00, 0.01]	[−0.93, 0.45]
Observations	8854	8854	8854	8854	8854	7958
Neighborhoods	240	240	240	240	240	238
Mean DV	3,105.91	49.30	0.04	0.92	0.01	5.42
SD DV	430.15	2.23	0.20	0.27	0.10	2.38

Notes: This table presents the results from OLS regressions with birth weight, height, and Apgar 1 min greater or equal than seven as the dependent variables using data from 2002 to 2003. Orion is a dummy that takes the value of one for treated neighborhoods after exposure to the intervention. All columns show the two-way fixed effects estimates using the following specification $Y_{int} = \alpha + \eta_n + \delta_t + \beta \cdot Orion_n \times Post_t + \theta X_{it} + \varepsilon_{int}$. All columns include the following controls: mother's and father's age, dummies for the type of insurance, dummies for mother's and father's educational attainment, dummies for mother's marital status, number of previously born alive, number of pregnancies, and whether the newborn if female. Robust standard errors clustered by neighborhood are reported in parentheses. 95% confidence intervals (C.I.) using wild cluster bootstrap with 1000 replications reported in brackets. Significance levels according to t-statistic: 1% ***, 5% **, 10% *.

Data availability

The data and replication files are available through Mendeley data here (Cortes, Gómez, Posso, & Suárez, 2024).

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