Gunshot Noise and Birth Outcomes

Preliminary draft: Please do not circulate

Anna Jaskiewicz and Michael Topper*
Draft Date: November 20, 2023

Abstract

Gun violence is ubiquitous across the United States, with gun-related deaths reaching an all-time high in 2021. The prevalence of gunfire results in loud and potentially stress-inducing sounds, which may adversely affect critical stages of in-utero development. However, gunfire is largely unreported, creating a unique challenge for researchers to understand its consequences. In this paper, we mitigate this shortcoming by leveraging data from ShotSpotter—an acoustic gunshot technology which uses an array of sensors placed on city structures to detect the sound of gunfire. We combine this unique data source with the universe of births in San Francisco over a four-year period (2016-2020), each matched to a mother's residence. Using the variation in gunfire detections from ShotSpotter at the census-block level, we employ a difference-in-differences methodology and find that gunshot noise creates substantial decreases in gestation lengths, resulting in an increase in preterm deliveries. These effects are driven entirely by times of the day when civilians are awake, and are particularly concentrated among mothers with low levels of education. These results suggest that gunshot noise is a major factor contributing to the income inequities in pregnancy outcomes.

JEL Codes: I14, I18, K42

*Department of Economics, University of California Santa Barbara. (Corresponding author: ama187@ucsb.edu).

1 Introduction

In 2021, United States witnessed a grim milestone with nearly 700 mass shootings, an over 150% increase relative to 2014 (Gun Violence Archive, 2023), reflecting a broad uptick in gun-related violence across the country. While a growing body of scholarly work documents the adverse impact of mass shootings on birth outcomes (Dursun, 2019; Banerjee and Bharati, 2020), substantially less severe instances of gun-related violence can also negatively affect maternal and infant health. Merely hearing a gunshot in one's neighborhood of residence can profoundly shape a pregnant individual's perception of safety and future victimization risk, influencing their psychological well-being and altering their daily routines. However, as gunshot noise remains largely under-reported, there exists little empirical evidence demonstrating its effects on birth health.

This study addresses this challenge by utilizing novel data obtained through ShotSpotter, an automated gunshot detection technology which relies on sensors placed on buildings and street lamps, circumventing the need for civilian reporting. By merging ShotSpotter data with restricted-access information on the universe of births in San Francisco, we analyze the effect of hearing gunshot noise during pregnancy on infant health. Our findings show that in utero exposure to gunshot noise is linked to shorter gestation periods and a higher risk of preterm and very preterm deliveries. These effects are driven by exposure to gunshot noise during waking hours and disappear completely during sleeping hours, despite a substantial number of detections during night time. Moreover, the impact of gunshot noise is more pronounced among mothers with relatively low levels of education, underscoring the heightened vulnerability of already underprivileged demographics to the adverse effects of gunshot noise. The results are also robust to compositional changes in the profile of mothers giving birth.

This research makes significant contributions to several areas of scholarly work. First, it expands on the existing body of literature studying the negative outcomes of crime exposure in utero. While previous studies in this space to a large extent relied on broadly defined county-level exposures, we enhance our geographic precision by utilizing highly localized exposure data at the census block group level (Dursun, 2019; Banerjee and Bharati, 2020). Second, we add to the literature on the broad health impacts of gun-related violence. Existing research often focused on highly acute and rare instances of gun-related crime, such as mass shootings and school shootings (Soni and Tekin, 2020; Cabral et al., 2020). We complement this body of work by examining the impact of a relatively less acute but more frequent type of gun-related stress, i.e., gunshot noise. Lastly, we add to the scholarship leveraging ShotSpotter as a data source. In the past, scholars have used ShotSpotter to measure how crime (as well as civilian reporting of crime) responds to changes in government policy (Carr and Doleac, 2014) and high-profile instances of police brutality (Ang et al., 2021). More recent work examines how ShotSpotter implementation affects the effectiveness of police officers (Topper, 2023). However, to our best knowledge no work has applied ShotSpotter data in the context of health outcomes.

The sections of this paper are organized as follows: Section II discusses the relevant literature, Section III describes the data used, Section IV explains the identification strategy, Section V outlines the results, and Section VI concludes.

2 Literature Review

2.1 In Utero Stress and Birth Outcomes

In Utero Stress & Birth Outcomes. Health at birth serves as the first measure of human capital accumulation. This is because health at birth affects one's health in adolescence and adulthood as well as a range later life non-health outcomes, including educational attainment (Royer, 2009). An important mechanism explaining this connection, extensively explored in recent economic literature, is the *fetal programming hypothesis* (Almond and Currie, 2011; Almond et al., 2018). Initially developed by epidemiologist David Barker to connect nutritional deficiencies in utero with increased susceptibility to adverse later life outcomes, the hypothesis has been increasingly applied in the context of psychological stress experienced by a mother as a result of exposure to events such as natural disasters, acts of terrorism, rocket attacks, armed conflict, homicides, mass shootings, domestic violence, and the loss of a family member (Torche, 2011; Brown, 2018; Camacho, 2008; Quintana-Domeque and Rodenas-Serrano, 2017; Lichtman-Sadot et al., 2022; Mansour and Rees, 2012; Currie et al., 2022).

Existing literature which investigates the effects of in utero stress on birth outcomes frequently reports adverse effects especially when the exposure occurs during the early stages of pregnancy (Duncan et al., 2016; Dursun, 2019). The substantial impact of early pregnancy stress on birth outcomes is frequently associated with the concept of "placental clock" (McLean et al., 1995; Herrera et al., 2021). When stress exposure takes place early during the pregnancy, the fetus may undergo "programming" for preterm delivery. This is because elevated levels of the corticotrophin-releasing hormone early in pregnancy—typically released by the pituitary gland in response to stress but also released by the placenta during gestation—are linked to a higher incidence of preterm deliveries (Schetter, 2009).

2.2 Effects of Crime Victimization and Exposure

The literature extensively documents the adverse impacts of crime on individuals who are directly victimized. Physical health is directly affected by victimization if the criminal act results in bodily injury. Even in the absence of bodily harm, victims often experience mental health distress (Cornaglia et al., 2014). Moreover, crime victimization has been shown to influence non-health-related outcomes, including career trajectories (Bindler and Ketel, 2022).

Crime affects not only those directly victimized. These effects are particularly pronounced for individuals who strongly identify with the victims, such as those residing in the same area or belonging to the same racial group (Powdthavee, 2005; Bindler et al., 2020). However, it is essential to acknowledge that for a crime incident to influence the outcomes of individuals not directly victimized, there must exist a mechanism for these individuals to learn about the crime. Consequently, studies utilizing geographical variation too coarse to allow for direct witnessing of the crime employ media coverage as a pathway. To this end, Banerjee and Bharati (2020) utilize exogenous variation in news coverage of mass shootings to illustrate that media coverage mediates the relationship between mass shootings in the mother's county of residence and birth outcomes. Similarly, Curtis et al. (2021) correlate highly publicized instances of anti-Black violence, as proxied by the number of Google searches, with an increase in worse mental health days among Black Americans.

3 Data

3.1 Birth Data

Restricted-access birth records are obtained from the California Department of Public Health. The data cover the universe of births in California and include information on mothers' addresses of residence, mothers' demographics as well as pregnancy and infant characteristics.

We construct six main birth outcome variables: *Birth weight*, *Low birth weight*, *Very* *low birth weight*, *Gestation length*, *Pre-term delivery*, and *Very pre-term delivery*. *Birth weight* captures an infant's weight at birth in grams; *Low Birth Weight* and *Very low Birth Weight* are indicator variables that take the value of one when an infant's birth weight is, respectively, less than 2,500 grams and less than 1,500 grams (World Health Organization, 2014); *Gestation length* captures the gestation length in weeks; *Pre-term delivery* and *Very pre-term delivery* are indicator variables that take the value of one when the gestation length is less than 37 weeks and 34 weeks, respectively (World Health Organization, 2018). To enable the merge with gunshot and crime data, we map each mother's address of residence to a census block group identifier.

Panels B and C of Table 1 summarize the birth outcomes and demographic characteristics of mothers in the sample. An average mother in the sample is nearly 32 years old, and nearly 70% of the mothers in the sample have completed at least some college degree. Around 7% percent of infants are born pre-term, lower than the 10.5% nationwide (World Health Organization, 2018).

3.2 Gunshot and Crime Data

We obtain both gunfire and crime data from the San Francisco Police Department's real-time law enforcement dispatches for police service. The data contains all 911 emergency calls that result in a police dispatch in addition to any police-initiated activity in the field upon viewing an incident. According to San Francisco Police Department, 40% of 911 calls are accidental or do not require police assistance. Therefore, these calls represent situations which necessitate police intervention.

To identify the occurrence of gunfire, we exploit the San Francisco Police Department's utilization of ShotSpotter technology. ShotSpotter is an acoustic gunfire detection software which uses an array of microphones and sensors placed on street lamps and buildings across the city to identify, locate, and rapidly dispatch police to the sound of gunfire. The sensors are wirelessly connected to servers and are equipped with artificial intelligence in order to detect the sound of gunfire. In San Francisco, six of the ten police districts have ShotSpotter sensors installed.[1] Given that only 12% of gunfire is reported by civilians (Carr and Doleac, 2016), ShotSpotter represents a novel way to more closely capture the true incidence of gunfire, bypassing the reliance on human reporting.

The technology utilizes a machine-learning algorithm in order to decipher gunshot noises from other sounds such as fireworks or car-backfires. Once a sensor detects a gunshot, a recording of the sound is forwarded to ShotSpotter's 24-hour review center where an expertly trained employee checks the recording for false positives. After confirmation, the information is sent to the police communications department where police officers are subsequently dispatched.[2] These dispatches are assigned a unique identification code which classifies the dispatch as ShotSpotter-initiated.

ShotSpotter sensors cannot capture every instance of gunfire, although the company claims that the sensors have 97% accuracy with a 0.5% false-positive rate. One field study finds a lower accuracy rate of roughly 81%, although the study was conducted in ShotSpotter's infancy (Goode, 2012; Irvin-Erickson et al., 2017; Mazerolle et al., 1998). Over the past decade, both the company and police departments claim that the technology has greatly improved. Moreover, although not specifically verifying the accuracy, multiple studies have shown that ShotSpotter implementation results in greater numbers of gun-related dispatches. Hence, ShotSpotter detections are a way to more precisely measure the presence of gunfire in comparison to 911 reports.

[1] According to a Freedom of Information Act, San Francisco has approximately 20 sensors per square mile.

[2] This entire process, according to the SoundThinking, ShotSpotter's parent company, takes under 60 seconds.

3.3 Sample Restrictions

We restrict our sample to years 2016 through 2020. A short time horizon enables us to leverage comparisons that are less sensitive to time effects. We also only consider census block groups covered by ShotSpotter sensors, which allows us to consistently measure gunshot detections.

4 Empirical Strategy

4.1 Baseline Specification

To estimate the effect of gunshot noise on birth outcomes, we use the following regression framework:

$$Y_{icmy} = \alpha + \Sigma_{t=1}^{3} \beta_t ShotSpotter_{cmy}^{t} + \gamma X_{imy} + \xi Z_{cmy} + \pi_c + \rho_{my} + \upsilon_{icmy} \quad (1)$$

where Y_{cmy} denotes birth outcomes of mother i residing in census block group c, with a child conceived in month m and year y, and $ShotSpotter_{cmy}$ represents the number of ShotSpotter alerts in census block group c in trimester t during pregnancy that started in month m and year y, X_{cmy} is a vector of observable maternal characteristics (age and education categories, sex of the infant, race and ethnicity categories, and the number of prior live births), Z_{cmy} is a vector of observable census block group characteristics (number of violent crimes during each trimester of pregnancy and number of non-violent crimes during each trimester of pregnancy). Census tract and month-by-year fixed effects are denoted by, respectively, π_c and ρ_{my}; υ_{cmy} is the error term, and the standard errors are clustered at the census block group level.

Throughout the paper, the model is estimated separately for waking-time ShotSpotter gunshots and non-waking time ShotSpotter gunshots.

4.2 Identification

The main coefficients of interest are β_t for $t \in \{1,2,3\}$. These capture the effect on birth outcomes of an additional gunshot detected by ShotSpotter during, respectively, the first, second, and third trimester of pregnancy. Trimesters are defined in terms of relative to expected, as opposed to actual, month and year of conception (obtained by subtracting the length of gestation from the actual birth month and year) as well as expected, instead of actual, month and year birth (obtained by adding nine months to the expected month and year of conception). Expected month and year of conception and birth are used because actual date of birth may be endogenous to exposure to gunshot noise, as shorter gestation length decreases the likelihood of exposure to gunshot noise.

It is important to note that β_t for $t \in \{1,2,3\}$ does not enable us to separate the effects of merely hearing the gunshot noise and the effect related to the police dispatch following a ShotSpotter alert. Increased police presence has been associated with adverse birth outcomes among minority mothers (Hardeman et al., 2021). Therefore, our coefficients capture both the stress associated with hearing the gunshot as well as the stress associated with higher likelihood of contact with the police.

Our identification relies on the assumption that the timing of exposure to gunshot noise is not related to unobservable factors that could also affect mother's birth outcomes. In Table 7, we verify the plausibility of this assumption by showing that exposure to gunshot noise does not impact the demographic characteristics of mothers. We also conduct a placebo test to check that gunshots experienced *after* delivery do not affect birth outcomes. Visual inspection of Figures 3 and 4 confirms the absence of post-trends, especially for gestation length-related variables.

5 Results

Table 2 provides the effects of awake-time gunshots during each trimester of pregnancy on birth outcomes, estimated using equation (1). In column 1, the outcome variable is the average gestation length in weeks; in column 2, the outcome variable is pre-term delivery (gestation length <37 weeks); in column 3, the outcome variable is very pre-term delivery (gestation length <34 weeks); in column 4, the outcome variable is birth weight in grams; in column 5, the outcome variable is low birth weight (birth weight <2,500 grams); finally, in column 6, the outcome variable is very low birth weight (birth weight <1,500 grams).

In utero exposure to awake-time gunshot noise is related to adverse birth outcomes. As shown in Table 2, an additional awake-time gunshot during the first trimester of pregnancy is associated with a 0.110 week reduction in gestation length (0.3% relative to the mean), a 0.013 percentage point increase in the risk of pre-term delivery (17.6% relative to the mean), as well as a 0.013 increase in the risk of very pre-term delivery (72.2% relative to the mean). An extra awake-time gunshot during the first trimester of pregnancy is also associated with a 19.023 gram decrease in birth weight (0.6% relative to the mean), a 0.007 percentage point increase in the risk of low birth weight (10.9% relative to the mean), as well as a 0.005 increase in the risk of very low birth weight (55.5% relative to the mean), although only the effect on very low birth weights is statistically significant.

The effects are concentrated in the first trimester of gestation. Exposure to awake-time gunshot noise very close to one's residence is likely to induce production of hormones typically involved in a stress response, and "placental clock" refers to the idea that such hormonal changes early during the pregnancy may "program" the fetus for premature birth (McLean et al., 1995; Herrera et al., 2021). The finding that effects are driven by exposures during the initial trimesters is consistent with existing literature on in utero exposure to stress and birth outcomes (Duncan et al., 2016; Dursun, 2019).

It is interesting to note the the magnitude of the reported effects is rather substantial. For reference, Dursun (2019) finds that a mass shooting in mother's county of residence during pregnancy is linked with a 7.7% increase in the incidence of very low birth weights and a 6.9% increase in the incidence of very pre-term births. The effects we report here are approximately 10 times as large as the ones reported by Dursun (2019), which is likely thanks to our ability to capture the effects of gunshot noise occurring within a very close proximity to the mother's residence. The effects we report here are similar in size to the effects of other individual-level and very direct stressors, such as losing a family member during pregnancy (Persson and Rossin-Slater, 2018).

Table 3 provides the results when equation (1) is used to estimate the effects of non-awake-time gunshots during each trimester of pregnancy on birth outcomes. We find no evidence of non-awake-time gunshots affecting birth outcomes. This may be because mothers may not be aware of these gunshots in the same way that they are of awake-time gunshots, subsequently diluting the potential stress response.

The effects of awake-time gunshots on birth outcomes survive and remain stable in magnitude when both crime controls and mother demographic controls are excluded as well as when only crime controls are excluded (see Table 4). This shows that gunshots capture something something very distinct from the effect of crimes in general (both violent and non-violent) and are likely more salient to civilians.

The effects are concentrated among the most vulnerable populations. Table 5 provides the results when equation (1) is estimated separately for mothers with at most high school diploma (in Panel A) and strictly more than high school education (in Panel B). The effects are driven by mothers with relatively lower levels of education. Mothers with lower levels of education may be under-employed or unemployed at higher rates than mothers with relatively high levels of education. Thus, such mothers may be more likely to actually be at home at the time of the gunshot alert by ShotSpotter. Moreover, these mothers may have less access to resources to mitigate the negative impact of stress exposure, such as family networks.

Relatedly, the effects are concentrated in areas with relatively high levels of gunshot noise. Table 6 shows the coefficients when equation (1) is estimated for mothers residing in areas with above average levels of waking-time gunshot noise (Panel A) and below average levels of waking-time gunshot noise (Panel B). The effects are driven by exposures in the former areas. Individuals exposed to a gunshot but residing in an area with a relatively low level of gunshot noise may treat the gunshot as a one-off event and not very indicative of future crime levels.

Table 7 shows the results when equation (1) is used to predict the effects of waking-time gunshots on mothers' demographic characteristics. We find no evidence of the effects on birth outcomes being affected by changes in the composition of mothers giving birth as waking-time gunshots across all trimesters do not affect the age at which mothers give birth, whether the mother had any previous births, and the sex of the infant. While there is a small increase in the probability of mother having at most high school education, the effect is only marginally significant.

To verify that trends in unobservable characteristics associated with gunshot noise do not affect birth outcomes, we conduct a placebo test estimating the effect of gunshots occurring after expected delivery on birth outcomes. Figures 3 and 4 show the effects of waking-time gunshots during pregnancy and up to 10 months after expected birth on birth outcomes. We find no evidence of post-trends in case of gestation length, preterm delivery, and very pre-term delivery. The effects on birth weight, low birth weight, and very low birth weight are slightly less robust; however, our major significant results are related to gestation length, preterm birth, and very pre-term birth.

6 Conclusion

Gun-related violence has surged in recent years, with both high-profile mass shootings and less severe gun-related crimes on the rise across the country. However, tracking the health implications of the latter has been a challenge for researchers due to under-reporting. This paper overcomes this obstacle by leveraging novel data from ShotSpotter, an automatic gunshot detection technology. Through combining ShotSpotter's gunshot data with the universe of birth records in San Francisco, we document the inter-generational impact of exposure to gunshots noise in utero.

Even though hearing gunshots represents a relatively less acute form of stress, we document significant adverse effects on birth outcomes, particularly pronounced in infants born to mothers with lower levels of education. The magnitude of these effects is substantial, similar to the loss of a family member. The effects are driven entirely by exposures during waking times, when mothers are more likely to be aware of the activity outside, and disappear during non-waking times.

One of the key strengths of this study is that we manage to identify exposures at a very fine geographic level, which potentially allows for direct witnessing of the gunshot noise. In contrast, much prior work in the birth outcome space has relied on county-level exposures, which likely involve mothers learning about the crime incident through the news media instead of witnessing it directly. At the same time, our study has several important limitations. First, we focus on mothers residing in San Francisco. This both reduces our power but also poses challenges for external validity. Future research should strive to collect a broader range of data, potentially spanning other cities. Furthermore, as mentioned before, our estimates capture the effect of stress associated with both gunshot noise as well as increased police presence. Future work should aim to collect data on police dispatches to particular locations to isolate these effects.

A preliminary back-of-the-envelope calculation suggests that the annual social costs linked to exposure to gunshot noise in San Francisco reach nearly 2.5 million USD annually.[3] This emphasizes the critical need for policymakers to target efforts to mitigate gun violence as well as for researchers to engage in work to better understand its consequences.

[3] This is the cost associated with one additional very low birth weight infant (Currie et al., 2022).

References

Almond, D. and Currie, J. (2011). Killing Me Softly: The Fetal Origins Hypothesis. *Journal of Economic Perspectives*, 25(3):153–172.

Almond, D., Currie, J., and Duque, V. (2018). Childhood Circumstances and Adult Outcomes: Act II. *Journal of Economic Literature*, 56(4):1360–1446. Publisher: American Economic Association.

Ang, D., Bencsik, P., Bruhn, J., and Derenoncourt, E. (2021). Police violence reduces civilian cooperation and engagement with law enforcement. *SSRN Electronic Journal*.

Banerjee, R. and Bharati, T. (2020). Mass shootings and Infant Health in the United States. Economics Discussion / Working Papers 20-16, The University of Western Australia, Department of Economics.

Bindler, A. and Ketel, N. (2022). Scaring or scarring? labor market effects of criminal victimization. *Journal of Labor Economics*, 40(4):939–970.

Bindler, A., Ketel, N., and Hjalmarsson, R. (2020). Costs of victimization. *Handbook of Labor, Human Resources and Population Economics*, page 1–31.

Brown, R. (2018). The Mexican Drug War and early-life health: The impact of violent crime on birth outcomes. *Demography*, 55(1):319–340.

Cabral, M., Kim, B., Rossin-Slater, M., Schnell, M., and Schwandt, H. (2020). Trauma at school: The impacts of shootings on students' human capital and economic outcomes. Working Paper 28311, National Bureau of Economic Research.

Camacho, A. (2008). Stress and birth weight: Evidence from terrorist attacks. *American Economic Review*, 98(2):511–515.

Carr, J. and Doleac, J. L. (2016). The Geography, Incidence, and Underreporting of Gun Violence: New Evidence Using Shotspotter Data.

Carr, J. B. and Doleac, J. L. (2014). Keep the kids inside: Juvenile curfews, bad weather, and urban gun violence. *SSRN Electronic Journal*.

Cornaglia, F., Feldman, N. E., and Leigh, A. (2014). Crime and mental well-being. *Journal of Human Resources*, 49(1):110–140.

Currie, J., Mueller-Smith, M., and Rossin-Slater, M. (2022). Violence while in utero: The impact of assaults during pregnancy on birth outcomes. *The Review of Economics and Statistics*, 104(3):525–540.

Curtis, D. S., Washburn, T., Lee, H., Smith, K. R., Kim, J., Martz, C. D., Kramer, M. R., and Chae, D. H. (2021). Highly public anti-black violence is associated with poor mental health days for black americans. *Proceedings of the National Academy of Sciences*, 118(17).

Duncan, B., Mansour, H., and Rees, D. I. (2016). It's just a game. *Journal of Human Resources*, 52(4):946–978.

Dursun, B. (2019). The Intergenerational Effects of Mass Shootings. *SSRN Journal*.

Goode, E. (2012). Shots Fired, Pinpointed and Argued Over (Published 2012) — nytimes.com. `https://www.nytimes.com/2012/05/29/us/shots-heard-pinpointed-and-argued-over.html`. [Accessed 01-10-2023].

Gun Violence Archive (2023). Past summary ledgers.

Hardeman, R. R., Chantarat, T., Smith, M. L., Karbeah, J., Van Riper, D. C., and Mendez, D. D. (2021). Association of Residence in high-police contact neighborhoods with preterm birth among Black and White individuals in Minneapolis. *JAMA Network Open*, 4(12).

Herrera, C. L., Bowman, M. E., McIntire, D. D., Nelson, D. B., and Smith, R. (2021). Revisiting the placental clock: Early corticotrophin-releasing hormone rise in recurrent preterm birth. *PLOS ONE*, 16(9).

Irvin-Erickson, Y., La Vigne, N., Levine, N., Tiry, E., and Bieler, S. (2017). What does gunshot detection technology tell us about gun violence? *Applied geography*, 86:262–273.

Lichtman-Sadot, S., Benshalom-Tirosh, N., and Sheiner, E. (2022). Conflict, rockets, and birth outcomes: Evidence from Israel's operation protective edge. *Journal of Demographic Economics*, pages 1–27.

Mansour, H. and Rees, D. I. (2012). Armed conflict and birth weight: Evidence from the al-Aqsa intifada. *Journal of Development Economics*, 99(1):190–199.

Mazerolle, L. G., Watkins, C., Rogan, D., and Frank, J. (1998). Using gunshot detection systems in police departments: The impact on police response times and officer workloads. *Police quarterly*, 1(2):21–49.

McLean, M., Bisits, A., Davies, J., Woods, R., Lowry, P., and Smith, R. (1995). A placental clock controlling the length of human pregnancy. *Nature Medicine*, 1(5):460–463.

Persson, P. and Rossin-Slater, M. (2018). Family ruptures, stress, and the mental health of the next generation. *American Economic Review*, 108(4-5):1214–52.

Powdthavee, N. (2005). Unhappiness and crime: Evidence from south africa. *Economica*, 72(287):531–547.

Quintana-Domeque, C. and Rodenas-Serrano, P. (2017). The hidden costs of terrorism: The effects on health at birth. *Journal of Health Economics*, 56:47–60.

Royer, H. (2009). Separated at girth: Us twin estimates of the effects of birth weight. *American Economic Journal: Applied Economics*, 1(1):49–85.

Schetter, C. D. (2009). Stress processes in pregnancy and preterm birth. *Current Directions in Psychological Science*, 18(4):205–209.

Soni, A. and Tekin, E. (2020). How do mass shootings affect community wellbeing? Working Paper 28122, National Bureau of Economic Research.

Torche, F. (2011). The effect of maternal stress on birth outcomes: Exploiting a natural experiment. *Demography*, 48(4):1473–1491.

World Health Organization (2014). Global nutrition targets 2025: Low birth weight policy brief.

World Health Organization (2018). Preterm birth.

Figures and tables

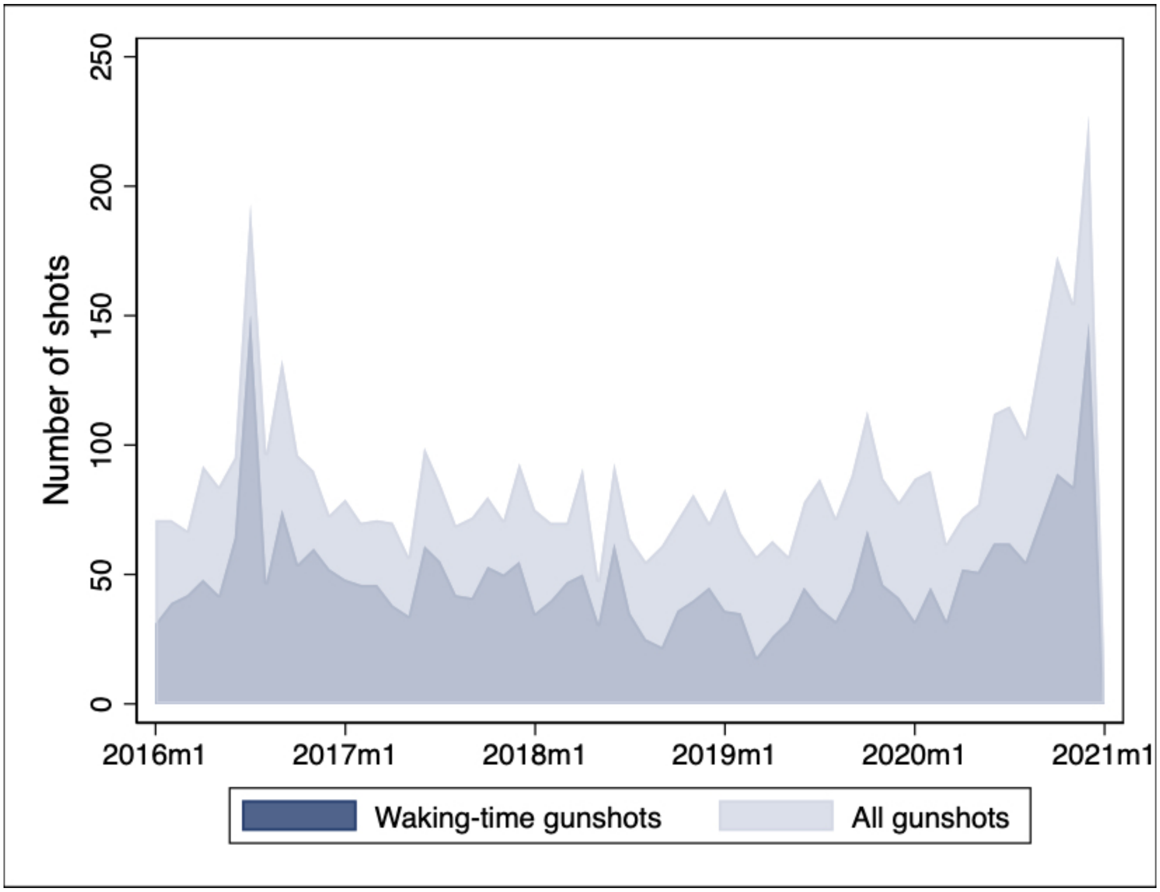
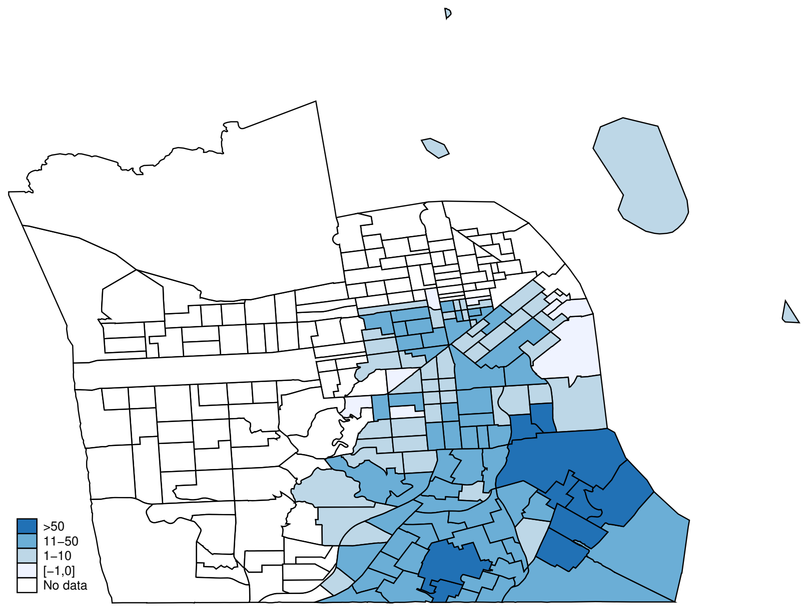
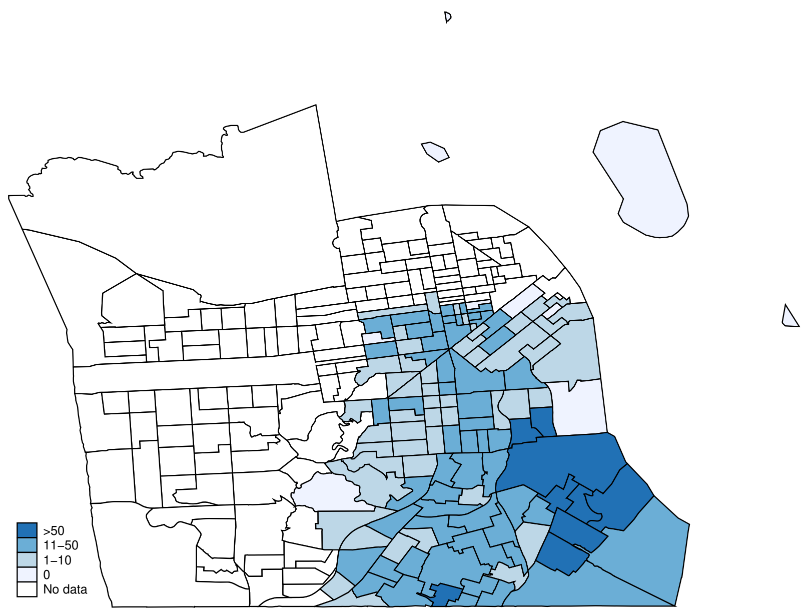


Figure 1: Monthly gunshots in San Francisco, 2016-2020.

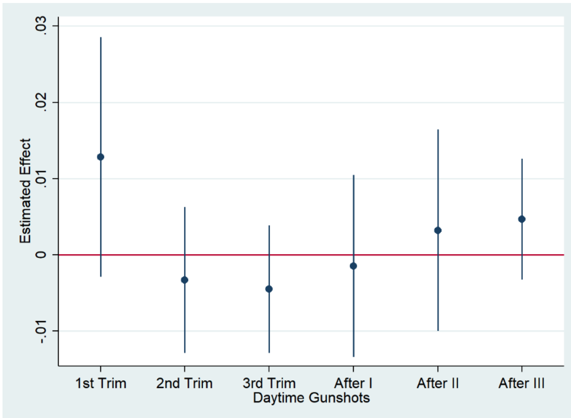


(a) Waking-time gunshots.

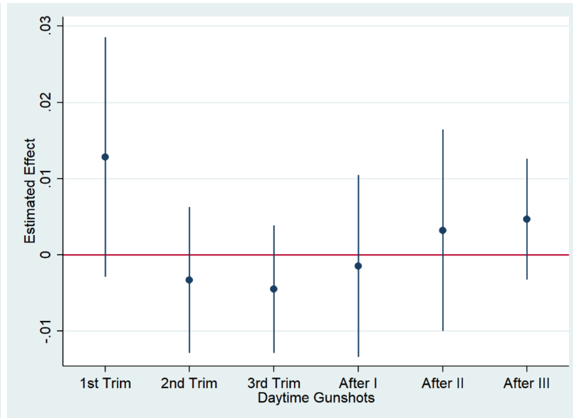


(b) Non-waking-time gunshots.

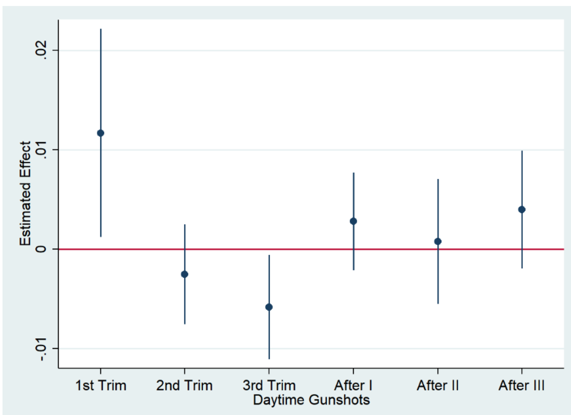
Figure 2: Geographic distribution of gunshots in San Francisco, 2016-2020.



(a) Gestation length (weeks).



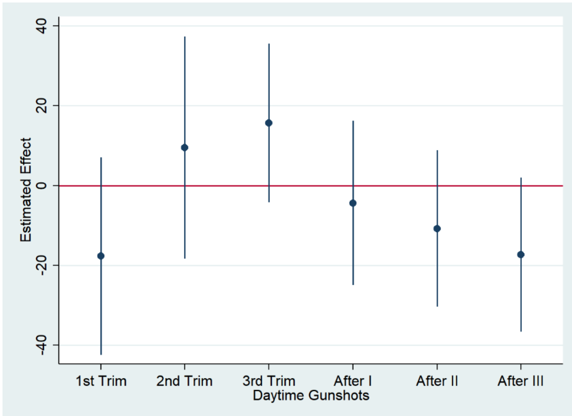
(b) Pre-term delivery (<37 weeks).



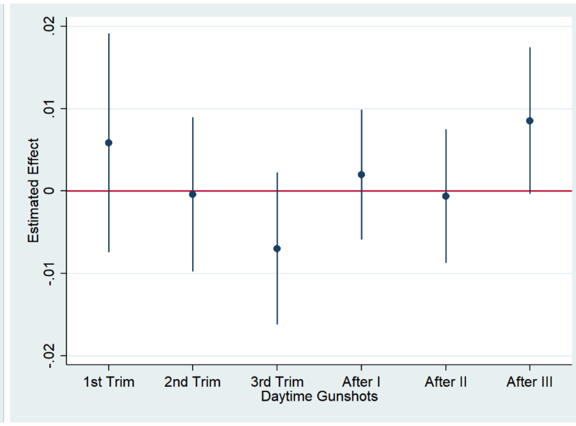
(c) Very pre-term delivery (<34 weeks).

Figure 3: Placebo test on gestation length, pre-term delivery, and very pre-term delivery.

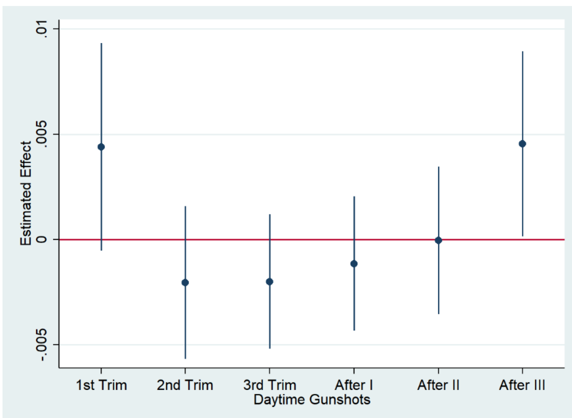
Notes: Each circle depicts a coefficient estimate and each whisker depicts the estimated 95% confidence interval from a model estimating the effect of waking-time gunshots on birth outcomes. “After I” refers to 1-3 months after estimated delivery; “After II” refers to 4-6 months after estimated delivery; “After III” refers to 7-10 months after estimated delivery.



(a) Birth weight (grams).



(b) Pre-term delivery (<2,500 grams).



(c) Very pre-term delivery (<1,500 grams).

Figure 4: Placebo test on birth weight, low birth weight, and very low birth weight.

Notes: Each circle depicts a coefficient estimate and each whisker depicts the estimated 95% confidence interval from a model estimating the effect of waking-time gunshots on birth outcomes. “After I” refers to 1-3 months after estimated delivery; “After II” refers to 4-6 months after estimated delivery; “After III” refers to 7-10 months after estimated delivery.

Table 1: Summary Statistics.

	Mean	**St. Dev.**	**Min**	**Max**
Panel A: Gunshot data				
Awake gunshots	0.041	0.240	0	5
Non-awake gunshots	0.031	0.195	0	6
Panel B: Birth outcomes				
Gestation length (weeks)	38.725	1.914	16	42
Pre-term delivery	0.074	0.261	0	1
Very pre-term delivery	0.018	0.133	0	1
Birth weight (grams)	3,270.273	541.908	200	5,290
Low birth weight	0.064	0.246	0	1
Very low birth weight	0.009	0.093	0	1
Panel C: Controls				
Mother's age	31.789	5.781	13	53
Male infant	0.497	0.500	0	1
At most high school	0.321	0.467	0	1
First infant	0.487	0.467	0	1
White	0.499	0.500	0	1
Asian	0.287	0.452	0	1
Other	0.209	0.407	0	1
Hispanic	0.351	0.477	0	1

Table 2: Effect of Waking-Time Gunshots on Birth Outcomes.

	Gestation length	**Pre-term delivery**	**Very pre-term delivery**	**Birth weight**	**Low birth weight**	**Very low birth weight**
	(1)	(2)	(3)	(4)	(5)	(6)
Waking gunshots-1st trim.	-0.110**	0.013*	0.013**	-19.023	0.007	0.005**
	(0.044)	(0.008)	(0.005)	(11.841)	(0.006)	(0.002)
Waking gunshots-2nd trim.	0.038	-0.003	-0.002	7.771	-0.001	-0.002
	(0.037)	(0.005)	(0.002)	(14.258)	(0.005)	(0.002)
Waking gunshots-3rd trim.	-0.007	-0.003	-0.005	10.253	-0.005	-0.001
	(0.031)	(0.004)	(0.003)	(10.020)	(0.005)	(0.002)
Observations	7,967	7,967	7,967	7,967	7,967	7,967
Mean of Dependent Variable	38.725	0.074	0.018	3,270.273	0.064	0.009

Note: *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 3: Effect of Non-Waking-Time Gunshots on Birth Outcomes.

	Gestation length	**Pre-term delivery**	**Very pre-term delivery**	**Birth weight**	**Low birth weight**	**Very low birth weight**
	(1)	(2)	(3)	(4)	(5)	(6)
Non-waking gunshots-1st trim.	-0.033	0.005	-0.000	-8.633	-0.004	0.000
	(0.046)	(0.007)	(0.004)	(16.292)	(0.005)	(0.003)
Non-waking gunshots-2nd trim.	0.032	-0.003	-0.002	13.726	0.003	0.000
	(0.055)	(0.008)	(0.005)	(13.253)	(0.007)	(0.003)
Non-waking gunshots-3rd trim.	-0.045	0.010	0.004	9.390	0.002	0.001
	(0.053)	(0.007)	(0.004)	(15.656)	(0.005)	(0.0003)
Observations	7,967	7,967	7,967	7,967	7,967	7,967
Mean of Dependent Variable	38.725	0.074	0.018	3,270.273	0.064	0.009

Note: *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 4: Alternative Control Specifications.

	Gestation length		Pre-term delivery		Very pre-term			Birth weight		Low birth weight		Very low birth weight	
	(1)	(2)	(3)	(4)	(5)	(6)		(7)	(8)	(9)	(10)	(11)	(12)
Waking gunshots-1st trim.	-0.115***	-0.109**	0.012	0.012	0.013**	0.013**		-18.326	-18.615	0.007	0.007	0.005**	0.005**
	(0.042)	(0.043)	(0.008)	(0.008)	(0.005)	(0.005)		(11.372)	(11.617)	(0.006)	(0.006)	(0.002)	(0.002)
Waking gunshots-2nd trim.	0.042	0.044	-0.004	-0.004	-0.002	-0.002		7.401	8.555	-0.000	-0.001	-0.002	-0.002
	(0.038)	(0.036)	(0.005)	(0.005)	(0.002)	(0.002)		(14.056)	(14.374)	(0.004)	(0.005)	(0.002)	(0.002)
Waking gunshots-3rd trim.	-0.016	-0.014	-0.002	-0.002	-0.004	-0.004		6.304	8.031	-0.004	-0.005	-0.001	-0.001
	(0.031)	(0.031)	(0.004)	(0.004)	(0.003)	(0.003)		(10.206)	(10.055)	(0.005)	(0.005)	(0.002)	(0.002)
Observations	7,967	7,967	7,967	7,967	7,967	7,967		7,967	7,967	7,967	7,967	7,967	7,967
Mean of Dependent Variable	38.725	0.074	0.018	3,270.273	0.064	0.009		38.725	0.074	0.018	3,270.273	0.064	0.009
Exclude crime controls	X	X	X	X	X	X	X		X	X	X	X	X
Exclude maternal controls	X		X		X			X		X		X	

Note: *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 5: Heterogeneity by Mother's Education Level.

	Gestation length	**Pre-term delivery**	**Very pre-term delivery**	**Birth weight**	**Low birth weight**	**Very low birth weight**
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. At most high school						
Waking gunshots-1st trim.	-0.179***	0.025*	0.017**	-22.477	0.015*	0.007**
	(0.066)	(0.013)	(0.009)	(20.038)	(0.009)	(0.003)
Waking gunshots-2nd trim.	0.074	-0.010*	-0.003	15.981	-0.008	-0.004
	(0.052)	(0.0 06)	(0.004)	(17.915)	(0.006)	(0.003)
Waking gunshots-3rd trim.	-0.053	-0.004	-0.007*	1.653	-0.007	-0.002
	(0.043)	(0.006)	(0.004)	(14.423)	(0.005)	(0.003)
Observations	2,548	2,548	2,548	2,548	2,548	2,548
Mean of Dependent Variable	38.517	0.087	0.022	3,242.483	0.075	0.011
Panel B. More than high school						
Waking gunshots-1st trim.	-0.034	-0.000	0.006	-12.872	-0.002	0.002
	(0.071)	(0.010)	(0.005)	(13.284)	(0.006)	(0.004)
Waking gunshots-2nd trim.	0.034	0.000	-0.002	7.286	0.003	-0.001
	(0.045)	(0.007)	(0.003)	(14.020)	(0.006)	(0.002)
Waking gunshots-3rd trim.	0.030	-0.003	-0.001	17.991	-0.004	-0.002
	(0.037)	(0.005)	(0.003)	(13.670)	(0.007)	(0.002)
Observations	5,409	5,409	5,409	5,409	5,409	5,409
Mean of Dependent Variable	38.824	0.067	0.016	3,283.403	0.059	0.008

Note: *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 6: Heterogeneity by Waking Gunshot Noise Levels.

	Gestation length	**Pre-term delivery**	**Very pre-term delivery**	**Birth weight**	**Low birth weight**	**Very low birth weight**
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Above average gunshot level						
Waking gunshots-1st trim.	-0.140***	0.014	0.015**	-14.456	0.006	0.006**
	(0.045)	(0.008)	(0.006)	(13.999)	(0.007)	(0.003)
Waking gunshots-2nd trim.	0.031	0.002	0.000	-1.208	0.003	-0.002
	(0.041)	(0.005)	(0.003)	(16.503)	(0.005)	(0.002)
Waking gunshots-3rd trim.	0.022	-0.002	-0.009***	14.957	-0.005	-0.005
	(0.034)	(0.005)	(0.003)	(10.820)	(0.005)	(0.002)
Observations	2,284	2,284	2,284	2,284	2,284	2,284
Mean of Dependent Variable	38.571	0.085	0.028	3,230.947	0.080	0.013
Panel B. Below average gunshot level						
Waking gunshots-1st trim.	0.101	-0.001	-0.001	-12.056	-0.006	-0.008***
	(0.115)	(0.017)	(0.008)	(32.791)	(0.013)	(0.003)
Waking gunshots-2nd trim.	0.014	-0.008	-0.016	52.695	-0.025*	-0.008***
	(0.102)	(0.019)	(0.003)	(34,500)	(0.014)	(0.002)
Waking gunshots-3rd trim.	-0.041	-0.009	0.003	4.652	-0.019	0.000
	(0.095)	(0.013)	(0.007)	(28.958)	(0.011)	(0.005)
Observations	5,683	5,683	5,683	5,681	5,681	5,681
Mean of Dependent Variable	38.787	0.069	0.014	3,286.092	0.058	0.007

Note: *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 7: Associations between Wake-Time Gunshots and Maternal Characteristics.

	Mother's age	At most high school	First child	Male child
	(1)	(2)	(3)	(4)
Waking gunshots-1st trim.	-0.057	0.013*	-0.005	0.003
	(0.104)	(0.008)	(0.007)	(0.007)
Waking gunshots-2nd trim.	-0.031	0.004	-0.009	-0.010
	(0.098)	(0.009)	(0.011)	0.009
Waking gunshots-3rd trim.	-0.166	0.002	0.001	-0.003
	(0.096)	(0.013)	(0.010)	(0.008)
Observations	7,967	7,967	7,967	7,967
Mean of Dependent Variable	31.789	0.321	0.487	0.497

Note: *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.