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The Mexican Drug War and Early-Life Health: The Impact of Violent Crime on Birth Outcomes

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Abstract This study examines the relationship between exposure to violent crime *in utero* and birth weight using longitudinal data from a household survey conducted in Mexico. Controlling for selective migration and fertility, the results suggest that early gestational exposure to the recent escalation of the Mexican Drug War is associated with a substantial decrease in birth weight. This association is especially pronounced among children born to mothers of low socioeconomic status and among children born to mothers who score poorly on a mental health index.

Keywords Birth outcomes · Crime · Selective fertility · Mexico

Introduction

Since 2008, Mexico has experienced a dramatic and unprecedented increase in violent crime. According to official data reported by the National Institute of Statistics and Geography (INEGI), homicides in Mexico were stable from the mid-1990s through 2007. However, between 2007 and 2010, the number of reported murders almost tripled, from 8,845 to 25,000. (See Fig. 1 for monthly homicide rates for the period 2000–2011.) This environment represents one of the most deadly internal conflicts in recent history.

Scholars have already begun to examine the short-term effects of the escalation in violence on economic and educational outcomes (Brown and Velásquez 2017; Dell 2015; Robles et al. 2013; Velásquez 2015). The purpose of the current study is to explore the impact of the rise in violent crime in Mexico on a group of particularly

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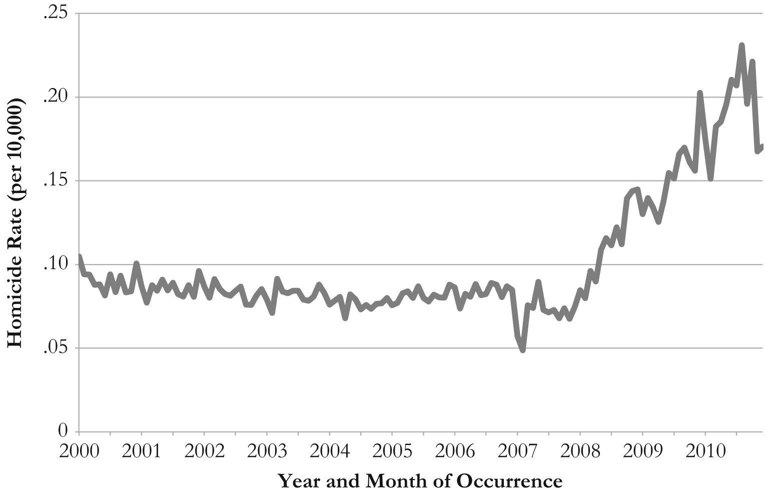

Fig. 1 Homicide rate by year and month in Mexico (per 10,000 population)

vulnerable individuals: infants. Specifically, in this article, I estimate the relationship between *in utero* exposure to violence and early-life human capital accumulation as measured by birth weight.

In utero exposure to violence could be related to birth weight via several potential mechanisms. Previous studies have provided evidence that psychological stress experienced by mothers during pregnancy can affect the intrauterine growth and gestational duration of the *in utero* child (Beydoun and Saftlas 2008; Black et al. 2016; Brown 2014; Camacho 2008). In addition, exposure to a daily stressor may change maternal health behaviors (e.g., smoking, exercise, prenatal care use) that could in turn affect the health of the fetus (Paarlberg et al. 1999). Last, exposure to violent crime in Mexico could be related to birth weight through the economic well-being of the household. Strong evidence suggests that the internal conflict in Mexico has reduced labor market participation and earnings (Dell 2015; Robles et al. 2013; Velásquez 2015), which could decrease the household's—and thus the pregnant mother's—consumption of nutritious food and vitamins.

Documenting the health consequences of any change in the environment, however, presents several challenges. In the case of violent crime, conflict intensity may be correlated with preexisting differences or trends in local characteristics that are also correlated with the health and well-being of mothers. Furthermore, behavioral responses—such as migration and family planning—may be related to both observed and unobserved characteristics of the mother and fetal health (Currie and Rossin-Slater 2013). Researchers working in this area face the difficult task of trying to disentangle the multiple routes through which *in utero* shocks could directly or indirectly impact maternal health. A significant advantage of the Mexican Family Life Survey (MxFLS), from which this study draws its data, is its information on the migratory and fertility behavioral responses that could be driving the relationship between birth weight and local violence.

This study makes two principal contributions to the literature. First, the analysis of the behavioral responses to violent crime provides evidence that families alter their fertility and/or migration decisions in response to increased local conflict in Mexico. Moreover, the results illustrate that failing to account for these systematic behavioral responses in this context leads to biased estimates. Second, through the use of detailed information on prenatal care, general maternal health activities, and maternal mental health status, this study provides evidence that the most likely link between violent crime exposure and adverse birth outcomes in Mexico is the biological response to maternal anxiety.

Background

Organized Crime's Leading Role in Violence in Mexico

Pregnant women in Mexico, the population of interest for this study, faced an environment in the late 2000s that was in stark contrast to the world they had lived in just a few years before. In particular, there was a dramatic increase in the potential for physical, mental, and financial harm. This study explores how this change in the environment affected the early-life health of the next generation.

The sudden change in the magnitude and conspicuousness of conflict related to the drug trade in Mexico, as well as the increasing spillover of violence onto civilian nonactors, has put an international spotlight on the Mexican "War on Drugs." This increased interest has led to an in-depth study of and vigorous debate about its causes (for excellent holistic descriptions of the conflict's history and actors, see Guerrero-Gutiérrez 2011; Rios and Shirk 2011; Robles et al. 2013). The general consensus, with varying opinions to the magnitude of each factor, is that the spike in homicides is a byproduct of three interrelated events.

One aspect is the increased success of the U.S.-Colombia fight to reduce the flow of drugs between the two countries, giving Mexican drug cartels extra incentive to control the increasingly profitable drug trade (Castillo et al. 2014). A second major influence was former president Felipe Calderón's initiation of a new federal strategy to unilaterally challenge all organized crime groups (OCGs), regardless of the size or location of the territory they controlled (Guerrero-Gutiérrez 2011; Molzahn et al. 2012). This tactic resulted in increased and geographically dispersed conflict throughout Mexico (Guerrero-Gutiérrez 2011). Last, when the military succeeded in capturing or killing a high-ranking cartel member, this would regularly result in intense fighting within the group to fill the power vacuum and eventually the fracturing of the original OCG into several new crime organizations (Guerrero-Gutiérrez 2011). The resulting struggle for control of valuable territory also changed the conflict environment for noncombatants as the OCGs increased the use of conspicuous violence and criminal activities targeting innocents as forms of intimidation. In addition, as profits from drug running reduced in size because proceeds needed to be split between more groups, OCGs increasingly turned to crimes against civilians, such as extortions, kidnappings, and car thefts (Guerrero-Gutiérrez 2011; Molzahn et al. 2012).

Conflict and *In Utero* Health: Pathways

Although generating evidence of a clear causal link has been difficult, a growing literature has concluded that intrauterine shocks can adversely affect fetal health as measured by birth weight (Almond and Currie 2011). Moreover, birth weight has been linked to long-run accumulation of human capital, such as height, IQ, earnings, and education (Behrman and Rosenzweig 2004; Bharadwaj et al. forthcoming; Black et al. 2007; Figlio et al. 2014; Rosenzweig and Zhang 2013). This relationship between birth weight and long-run economic outcomes suggests that if the Mexican Drug War is hindering fetal health, its impact may affect Mexico's economic development for years to come.

Violence could be related to birth weight through several routes. First, a growing literature examines the impact of maternal anxiety on the birth outcome of the *in utero* child. Animal experiments and small-sample human studies have shown that maternal stress is negatively correlated with intrauterine growth and gestational length (de Catanzaro and Macniven 1992; Mulder et al. 2002; Wadhwa et al. 2001). One theorized mechanism is that the body produces excess cortisol, norepinephrine, and epinephrine when confronting "worry, anxiety, and cognitive preparation for a threat" (McEwen 1998:175), and this reaction stimulates the supply of corticotropin-releasing hormone (CRH), which is strongly linked to intrauterine growth and parturition timing (Mancuso et al. 2004).

A different channel, suggested by Mulder et al., is through stress-induced arousal of the sympathetic nervous system, which can cause restricted blood flow to the fetus and result in decreased intrauterine growth (2002). The link between maternal anxiety and birth weight may also come from the relationship between stress and the immune system/inflammation (Wadhwa et al. 2001). Susceptibility to infection may be related to acute and chronic stress (Elenkov and Chrousos 1999; Segerstrom and Miller 2004), and infection may induce preterm birth. Specifically, cytokines released by the body to fight the infection may stimulate the production of hormones that prompt spontaneous labor. An additional pathway through which maternal stress may hinder birth outcomes is by elevating blood pressure. This elevated blood pressure may then cause hypertension and preeclampsia, which in turn can lead to preterm birth (Wadhwa et al. 2001).

Several studies have also posited that the timing of the stress exposure is important in determining its impact on fetal health, but debate still exists as to which trimester is most critical. One set of studies suggested that as a pregnancy progresses, the fetus is less and less at risk to fluctuations in maternal CRH levels because the mother is less reactive and has dampened sensitivity to stressful events (de Weerth and Buitelaar 2005; Schulte et al. 1990). Furthermore, CRH and cortisol levels naturally increase throughout pregnancy, which may in turn insulate the fetus from later-term maternal anxiety shocks. If these or similar mechanisms dominate, exposure to violence early in pregnancy would have the largest effects on birth outcomes. Alternatively, either through a relationship with the endocrine system or increased sensitivity to third trimester infection, late pregnancy could be the most important window for anxiety's relationship to birth outcomes. If these pathways are the most important, we would expect births with second and third trimester exposure to violence to be the most reactive.

Studies relying on natural experiments and within-family comparisons have been able to more credibly identify the impact of acute stress from violent events, such as landmine explosions (Camacho 2008) and armed conflict (Mansour and Rees 2012; Torche and Shwed 2015). These studies provided a consistent picture: maternal anxiety in early gestation leads to significantly poorer birth outcomes. The work of Mansour and Rees (2012), due to its use of a location-specific measure of intensity of violence exposure, is the most comparable with the current study. By using data on birth outcomes from Gaza and the West Bank collected during the al-Aqsa Intifada, Mansour and Rees provided strong evidence that exposure to local fatalities during the first trimester is negatively related to birth weight through its impact on maternal anxiety. Specifically, these authors found that an increase in fatalities in the district of birth nine to six months before birth lead to a statistically significant increase in the probability that the child will be born low birth weight (LBW; <2,500g).

Beyond the direct biological reaction to increased anxiety, pregnant mothers may also alter their behavior in response to realized or potential victimization. For example, the experience of increased stress and loss of control may lead to the escalation of risky behaviors, such as smoking and drinking (Paarlberg et al. 1999). Additionally, fear may change a woman's access to or use of prenatal health care, which has been associated with the quality of the birth outcomes in both developed and developing countries (Jewell 2007; Jewell and Triunfo 2006; Rosenzweig and Schultz 1983; Wehby et al. 2009). The direction of the effect is theoretically ambiguous because increased anxiety may result in women compensating for the health of the fetus by obtaining more health services, or the fear of potential victimization may reduce prenatal care use.

Prenatal care behavior may be particularly relevant in the Mexican context. Torche and Villarreal (2014), as I do in this study, examined the relationship between crime in Mexico and the birth outcomes of children exposed while *in utero*. They found that exposure to violence early in pregnancy led to *increased* birth weight and *decreased* probability of LBW. Their analysis of the potential mechanisms behind this result led them to attribute the gains in birth weight to pro-health behaviors—in particular, increased use of prenatal care. The authors discussed the potential for systematic behavioral responses to violence exposure in the Mexican context and explored these issues using Mexican birth registry and census data. From this analysis, they found no selective fertility response to violent crime and only limited evidence of a change in migration behavior.[1]

Finally, exposure to violence could also be related to birth weight through household income. Recent studies have examined the impact of the Mexican outbreak of violence on the income and earnings of the Mexican population (Dell 2015; Robles et al. 2013; Velásquez 2015). These studies found that the conflict has had a negative impact on the labor market participation and earnings of Mexican workers. If this reduction in resources restricted the intake of nutrients and vitamins, the health of the *in utero* child may have been negatively affected (Almond and Mazumder 2011).

[1] The strength of Torche and Villareal's study is its use of data from the Mexican birth certificate registry. One drawback of this data source, however, is that because of a lack of birth weight information prior to 2008, Torche and Villareal were able to study only a sample in which the majority of the births were conceived after the violent surge had already begun. In addition, the use of administrative data limited the authors' ability to fully explore or control for systematic fertility and migration responses. Specifically, because it was restricted to using data on births from 2008 to 2010, the analysis of the fertility response has limited information to generate the preescalation of violence trends necessary to fully identify variation in fertility behavior. In the case of the endogenous migration analysis, the use of census data forced the authors to focus on the migration behavior of all women of childbearing age rather than specifically those women giving birth in their sample period. Using the Mexican Family Life Survey, this study will be able to extend the behavioral response analyses in the dimensions mentioned and test the sensitivity of the focal birth weight estimates to explicitly controlling for systematic migratory and fertility behavior.

Data

The INEGI data provide information on all official reports of intentional homicides at the month and municipality level. An important advantage of the INEGI data versus other homicide data sources is that their collection period spans both the preconflict and conflict periods, allowing the temporal variation of homicide rates in Mexico to be combined with the panel nature of the MxFLS.

The MxFLS is an ongoing longitudinal data set that is representative of the Mexican population in 2002. During the 2002 baseline survey (MxFLS1), information was collected on approximately 8,440 households and 35,600 individuals among 150 communities and 16 states throughout Mexico. The second wave (MxFLS2) was conducted in 2005–2006; the third wave (MxFLS3) was initiated in 2009. Importantly for this study, attrition among women of childbearing age was very low (~6 %) and unrelated to violence exposure (see panel A in Table S1, Online Resource 1).

The timing of the MxFLS survey waves provides a useful snapshot of Mexico before and during the major rise in conflict. The first follow-up was conducted between 2005 and 2006, a period marked by low levels of violence. The second follow-up was performed from 2009 to 2013, during a period of extreme violence. Figure 2 provides maps of the homicide rate per 10,000 inhabitants for 2002, 2005, 2007, and 2009 at the municipality level. (See the online version of the article to view the figure in color.)

Although the Drug War has touched almost all of Mexico, its effect varies substantially across municipalities. For example, between 2005 and 2009, the homicide rate in some municipalities increased 30-fold, while it actually fell in a few others. Thus, in addition to the temporal variation in violence, this analysis will be able to exploit the geographic distribution of conflict exposure across municipalities. Given the great variation in conflict intensity growth between municipalities, an important issue to address is whether this violence heterogeneity actually reflects underlying trends in other municipality characteristics. To examine this question, a rich set of more than 30 preescalation of violence trends of the baseline MxFLS municipalities is used to predict each municipality's 2009 homicide rate as well as the change in homicide rate in each municipality between 2005 and 2009. Trends were created using the IPUMS samples of the 2000 and 2005 Mexican censuses and the MxFLS1 and MxFLS2 survey waves, reflecting a wide variety of demographic and economic characteristics as well as measures of municipality-level security and infrastructure. Table S2 of Online Resource 1 displays the results of these analyses. In both specifications, the estimates strongly suggest that preconflict trends in municipality characteristics were unrelated to future homicide rates.

The reproductive histories of the MxFLS used in this study were elicited from all household member women between ages 14 and 49. A first-order concern is that because MxFLS3 interviews extended to late 2009 and beyond, some observed pregnancies conceived after the surge in violence can no longer be reasonably thought of as unanticipated.

To address this problem, I conduct the primary analysis on a sample including only births between MxFLS1 and July 1, 2009 for panel member women in the MxFLS3

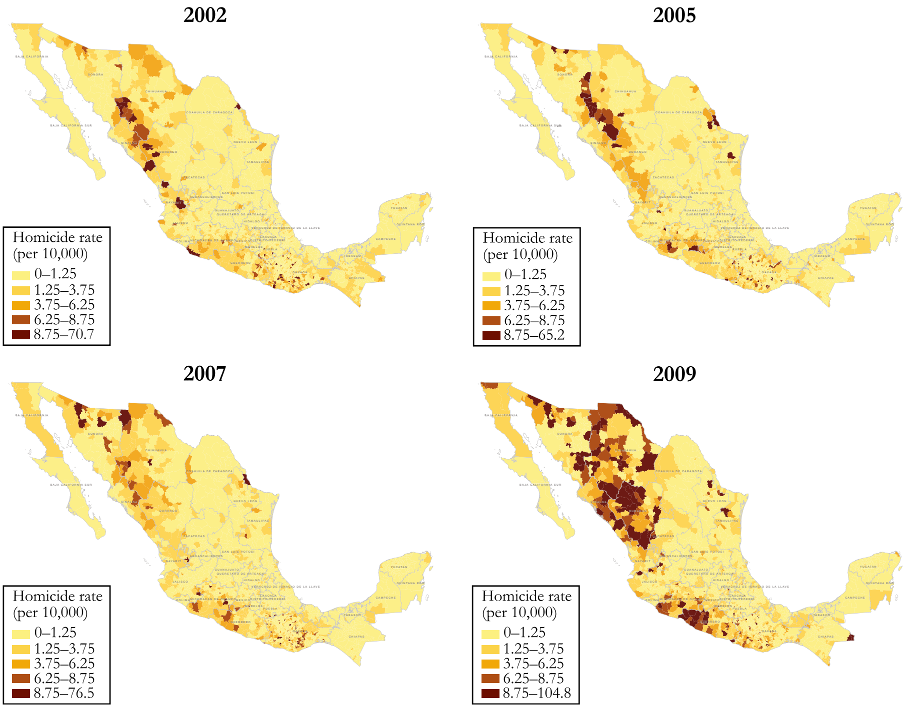

Fig. 2 Municipality homicide rates per 10,000 inhabitants

reproductive history (descriptive statistics shown in Table 1).[2] These births were conceived no later than the third quarter of 2008, when homicide rates had been elevated for only a few months but violence was still relatively new and less predictable. The analysis sample contains 1,868 live births to 1,392 women; a sibling is included in the data for 891 of these live births to 415 women.[3]

An important limitation of the MxFLS for this study is the lack of information on a critical aspect of the birth outcome: gestational length. Unfortunately, the MxFLS did not consistently or representatively ask for gestational age information. From the

[2] This sample selection choice also helps alleviate some additional internal and external validity concerns. First, the earliest interviews of MxFLS3 were conducted in August 2009. Thus, the birth records in MxFLS3 are only nationally representative up to July 2009. Second, a large-scale influenza outbreak occurred in Mexico in mid-2009; although not geographically correlated with the violence, this event could still limit the generalizability of the result. Last, although studies on the relationship in Mexico between violent conflict intensity and the level of Great Recession–inspired economic downturn have found no geographic relationship (Ajzenman et al. 2015), reasonable skepticism remains that even if the two events were not initially correlated, they may become intertwined over time (cartels may begin to gravitate toward areas with more or less recession exposure). As such, limiting the sample to those born by July 2009 assists in removing this potential confounding event.

[3] Specifically, 2,880 live births were recorded between MxFLS1 and July 1, 2009 to panel member women in the MxFLS3 reproductive history. I exclude information on 565 of these live births because they represent twins (20), duplicates (5), and nonrepresentative births from years prior to the date being elicited by the reproductive history (540). Thus, the ideal potential sample from the MxFLS if no pertinent information was missing would be 2,315 singleton live births. From this universe of 2,315 live births, I drop 447 observations (19 %) because of missing information on birth weight (100), date of birth (233), or interview date (114).

Table 1 Descriptive statistics

Homicide Rate	All Births to Panel Mothers in the MxFLS3 Reproductive History Since Baseline and Before Third Quarter of 2009 Full Sample (1)	 Sibling Sample (2)
Birth Outcomes		
Birth weight (g)	3,241.6	3,249.4
	(609.7)	(585.5)
Low birth weight (<2,500g) (%)	7.7	7.1
	(26.7)	(25.6)
Low birth weight+ (≤2,500g) (%)	10.9	10.7
	(31.1)	(30.9)
Premature birth (%)	18.7	16.5
	(39.0)	(37.1)
Any pregnancy complication (%)	8.4	6.5
	(27.7)	(24.7)
Male (%)	50.3	50.8
	(50.0)	(50.0)
Medical Care		
Born in hospital (%)	88.7	88.0
	(31.7)	(32.5)
Number of prenatal visits	7.7	7.3
	(4.0)	(3.7)
Prenatal care, first two months (%)	66.5	64.3
	(47.2)	(47.9)
Mother's Characteristics at Baseline		
Age	19.6	20.4
	(6.7)	(5.9)
Lived in rural locality (%)	51.1	51.6
	(50.0)	(50.0)
Year of education	7.6	7.9
	(3.4)	(3.1)
Employed (%)	31.0	30.0
	(46.3)	(45.9)
Earnings per month (pesos)	524.3	583.6
	(1,899.7)	(2,839.3)
Household per capita expenditure (pesos)	1,185.3	1,350.2
	(4,302.2)	(5,434.6)
Married (%)	30.0	30.2
	(45.8)	(46.0)
Number of Births	1,868	891
Number of Mothers	1,392	415

Notes: Standard deviations are shown in parentheses.

sibling sample, data on gestational age is available for only one-third of the observations, leaving only 139 nonrandom and nonrepresentative mothers to analyze. Given these limitations, exposure timing must be assigned based on a nine-month conception period prior to the birth month, and it is not possible to conduct an analysis of the impact of exposure to violence on gestational length or weight-for-gestational age.

Empirical Strategy and Results

Behavioral Responses: Migration and Fertility

The escalation of violent conflict in Mexico is likely to cause some Mexican citizens to respond systematically to alleviate potential harm and victimization. Recognizing, analyzing, and accounting for these responses is imperative to any study of the Mexican Drug War's impact on individual outcomes. Specifically, in the case of studying the effect of *in utero* exposure to violence on fetal health, two behavioral responses must be addressed: migration and family planning/fertility.

Systematic migration as a result of a realized or impending surge in crime could potentially change the composition of individuals exposed to violence and lead to biased results. The relationship between migration and potential exposure to violent crime among the mothers in the sample is explored in panel B of Table S1, Online Resource 1. The results of this analysis confirm that future local violence is associated with a significantly higher migration rate among the sample of interest. Given this threat to identification, the issue of endogenous migration will be addressed directly in the empirical strategy.

The second major behavioral response addressed in this study is selective fertility. To examine the impact of local violence on monthly birth rates of MxFLS1 municipalities, I estimate the following regression:

$$\begin{aligned} BR_{jym} = \sum_{i=10}^{15} \pi_i HOM(i \text{ months before } ym)_{jym} + \pi_1 HOM(9\text{–}7 \text{ months before } ym)_{jym} \\ + \pi_2 HOM(6\text{–}4 \text{ months before } ym)_{jym} + \pi_3 HOM(3\text{–}1 \text{ months before } ym)_{jym} \\ + \alpha + \gamma_y + \gamma_m + \delta_j + \sigma_{STATE,y} + \varepsilon_{jym}, \end{aligned} \tag{1}$$

where BR is the birth rate per 1,000 women of reproductive age of the relevant group in year y and month m, among women of reproductive age living in municipality j at baseline; $\sum_{i=10}^{15} \pi_i HOM(i \text{ months before } ym)_{jym}$ represents the homicide rate for each month from 10 to 15 months before the birth rate in year y, month m, and municipality j; $HOM(9\text{–}7 \text{ months before } ym)_{jym}$, $HOM(6\text{–}4 \text{ months before } ym)_{jym}$, and $HOM(3\text{–}1 \text{ months before } ym)_{jym}$ represent the municipality homicide rates over an approximation of the first, second, and third trimester of the outcome birth rate, respectively; and γ_y, γ_m, δ_j, and

$\sigma_{STATE,y}$ represent fixed effects at the year, month, municipality, and state × year level, respectively.[4]

Table 2 displays the findings from estimation of Eq. (1). The results from column 1 suggest that local homicide rates before conception and all the way through pregnancy did not significantly change overall birth rates. When looking at specific subgroups of the population, though, the results provide some evidence of endogenous fertility response. The estimates in column 2 suggest that birth rates respond negatively to conflict during the middle of gestation for higher-educated women ($\geq$9 years of education). Additionally, when the analysis is run on the birth rate of a subgroup of women in poorer health (represented by having a BMI > 25 or having a BMI > 30), the birth rate significantly decreases as a result of heightened conflict early in gestation. These results suggest that endogenous fertility decisions, left unaccounted for, could overestimate the effect of conflict exposure during the middle of gestation on birth outcomes and underestimate the effect of exposure early in gestation.

Birth Outcomes: General Results

This section presents results of an evaluation of the impact of local homicide rates during gestation, constructed as one to nine months before birth, on birth outcomes. The most straightforward way to view the relationship between the conflict in Mexico and birth outcomes is graphically. Figure 3 displays a graph plotting the INEGI-reported monthly national homicide rate alongside the monthly national birth weight, calculated using the MxFLS birth histories. This figure paints a clear inverse relationship between violent crime and birth outcomes in Mexico, but given the many potential pitfalls that exist in capturing the true impact of conflict on *in utero* health through regression analysis, I begin by proposing the strategies that will be used to confront these concerns.

As mentioned in the preceding section on behavior responses, migration decisions for mothers in the sample were significantly influenced by exposure to conflict. To avoid bias caused by endogenous migration, I use the mother's baseline (MxFLS1) municipality of residence, rather than the municipality of residence at birth or residence in MxFLS3, to assign exposure intensity.

Also, as discussed previously, birth rates among a nonrandom subset of women are related to conflict exposure. I address these concerns by using sibling comparisons. By making comparisons only within a family, I control for time-invariant characteristics of the mother/household. Additionally, in an attempt to limit the potential for time-varying within-family behavioral changes related to violence exposure biasing the results, I limit the sample to births conceived before violence levels could be predictably anticipated. Finally, I include available time-varying characteristics (mother's education, age at birth, employment status, earnings per month, and marital status; and household size, rural status, and per capita expenditure) between baseline and MxFLS2.

[4] I calculate the numerator for the outcome birth rate (*BR*) as the number of births in the MxFLS reproductive history. To create the denominator for the birth rate, I count the number of women aged 14–49 (and thus eligible to complete the reproductive history) in each wave of the MxFLS and considered the base January population in the year following the initiation of that wave of the MxFLS. Then I use a linear imputation method to fill in the months between waves. The period of this analysis runs to June 2009 because this is the latest date for which the MxFLS3 reproductive history is nationally representative.

Table 2 Impact of local homicide rate on birth rate at the municipality-month level from January, 2003 to June, 2009

	Birth Rate of Women Aged 14–49 (per 1,000)			
Homicide Rate	All (1)	≥9 Years of Education (2)	BMI >25 (overweight) (3)	BMI >30 (obese) (4)
t – 15 months	0.34	1.59	–0.86**	–1.18†
	(0.83)	(2.28)	(0.30)	(0.61)
t – 14 months	0.05	–0.75*	–0.49	–0.08
	(0.31)	(0.38)	(0.31)	(0.75)
t – 13 months	0.10	–0.14	–0.63*	–1.09†
	(0.31)	(0.43)	(0.29)	(0.63)
t – 12 months	–0.42	–1.22**	–0.56†	–1.75**
	(0.32)	(0.40)	(0.31)	(0.61)
t – 11 months	–0.21	–0.02	–0.76*	–1.28*
	(0.28)	(0.41)	(0.30)	(0.59)
t – 10 months	0.15	0.06	0.13	0.44
	(0.38)	(0.50)	(0.47)	(0.90)
t – 9 months	–0.04	0.04	–0.43	–0.05
	(0.30)	(0.44)	(0.32)	(0.69)
t – 8 months	0.19	0.05	–0.54†	–1.04†
	(0.34)	(0.48)	(0.30)	(0.53)
t – 7 months	0.20	0.02	0.61	–0.09
	(0.38)	(0.46)	(0.69)	(0.75)
t – 6 months	–0.33	–0.10	0.15	0.05
	(0.29)	(0.48)	(0.47)	(0.80)
t – 5 months	–0.31	–0.95*	0.11	–0.79
	(0.28)	(0.37)	(0.44)	(0.60)
t – 4 months	–0.21	–0.83*	0.47	0.86
	(0.33)	(0.34)	(0.75)	(1.26)
t – 3 months	–0.29	–0.75*	0.51	2.18
	(0.29)	(0.37)	(0.77)	(2.81)
t – 2 months	0.46	1.67	–0.18	–1.45*
	(0.48)	(1.06)	(0.55)	(0.60)
t – 1 month	0.28	–0.24	–0.02	–0.50
	(0.41)	(0.47)	(0.49)	(0.85)
Mean Monthly Birth Rate (1,000)	3.8	3.9	3.0	2.7
Municipality-Months	10,452	10,451	10,448	10,448

Notes: Homicide rates are per 10,000. Robust standard errors are shown in parentheses. Models include year, month, municipality, and state interacted with year fixed effects.

†$p < .10$; *$p < .05$; **$p < .01$

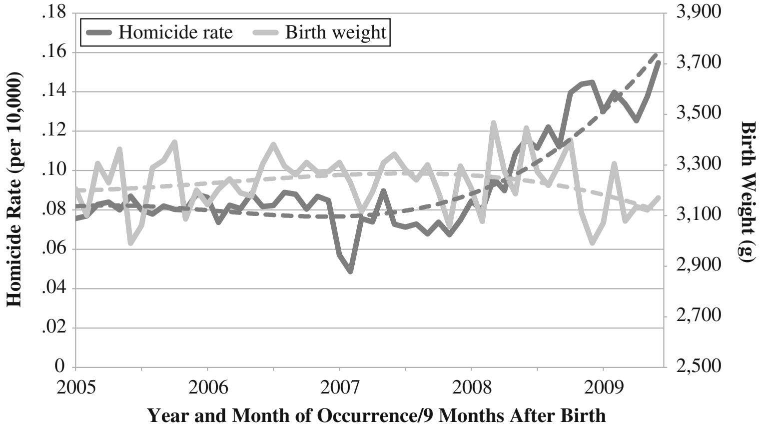

Fig. 3 Homicide rate (per 10,000 population) and birth weight (g) by year and month in Mexico

In addition, I include standard temporal (month of birth, year of birth, month of interview, and year of interview) and geographic (municipality of birth and state of birth linear time trend) fixed effects in the main specifications to control for any fixed relationship between the date of interview as well as the time and place of the birth and the reported birth outcome.

Finally, I include local homicide rates from before conception and after birth as controls. The results from the preceding section on behavior responses make it clear that behaviors related to family planning are being impacted by local violence several months before the potential conception month. To account for these fertility behaviors as well as other factors related to violence that may change the composition of maternal characteristics, even in a within-family comparison, I include the local homicide rates for 15 to 10 months before birth. In addition, perhaps local violence in the time surrounding a birth has a relationship to birth outcomes that is unrelated to its effect on the fetal health of the child. Thus, I add the homicide rate for the six months after birth to the regression because these homicides should be related to the local homicide rate during pregnancy but unrelated to birth outcomes and control for any additional spurious relationship.

The empirical strategy can be generalized in the following regression framework:

$$\begin{aligned} b_{ijtmk} = {} & \pi_1 HOM(\text{9–7 months before birth})_{tk} + \pi_2 HOM(\text{6–4 months before birth})_{tk} \\ & + \pi_3 HOM(\text{3–1 months before birth})_{tk} + \psi' \mathbf{X}_{itm} + \gamma_{YOB} + \gamma_{MOB} + \eta_{YOI} + \eta_{MOI} \\ & + \delta_j + \sum_{i=10}^{15} \pi_i HOM(i \text{ months before birth})_{tk} + \sum_{i=1}^{6} \pi_{-i} HOM(i \text{ months after birth})_{tk} \\ & + \sigma_{STATE,y} \times YOB + \nu_m + \varepsilon_{ijtmk}, \end{aligned} \tag{2}$$

where b is the birth outcome of individual i, born in municipality j, in time t, to mother m, who resided in municipality k at baseline; ν_m captures sibling fixed effects; γ_{YOB} are indicators of the year of birth; γ_{MOB} are indicators of the month of birth; η_{YOI} are indicators of the year of interview; η_{MOI} are indicators of the month of interview; δ_j are municipality of birth fixed effects; $\sigma_{STATE,\ y} \times YOB$ are state of birth fixed effects interacted with a year of birth linear trend; $\mathbf{X}_{itm}$ is a vector of individual (gender, birth order fixed effects, and survey wave) and time-varying mother/household characteristics; and $HOM(i \text{ months before birth})_{tk}$, $HOM(\text{9–7 months before birth})_{tk}$, HOM(6–

4 months before birth)$_{tk}$, *HOM*(3–1 months before birth)$_{tk}$, and *HOM*(i months after birth)$_{tk}$ are homicide rates in the municipality of mother's baseline residence, k, during specific periods before, during, and after gestation of individual i. To correct for the loss of independent variation in the homicide rate, as it is measured at the municipality level, I cluster standard errors at that same level.

Tables 3 and 4 present estimates from specifications that build up to Eq. (2). In column 1 of Table 3, using a specification without sibling fixed effects, it appears that local violence in the middle of gestation—four to six months before birth—is negatively related to a loss in birth weight, and exposure during the rest of gestation is nonsignificant. Even after I add the full set of controls other than the sibling fixed effects (Table 3, column 2), the magnitude of the estimate on exposure four to six months before birth remains negative and not significantly different than in column 1, and exposure in all other parts of gestation continues to have no relationship to birth outcomes. These estimates, though, may be driven by the change in fertility behavior presented in Table 2. It's important to note that moving to the sibling sample without including sibling fixed effect, found in column 3, does not change the relationship between violence and birth outcomes found in columns 1 and 2. This result, coupled with the fact that the mothers of the sibling sample have similar baseline characteristics as the full sample, supports the fact that any difference in the estimates between columns 1–2 and column 4 are not driven by the change in sample.

In column 4, the sibling fixed effects are introduced. As predicted from the endogenous fertility results, after maternal fixed effects are included, the sign of the effect from exposure four to six months before birth is reversed, and the absolute magnitude is greatly diminished. Additionally, the estimates, which now control for the positive maternal health composition bias as well as any other mother-specific unobserved heterogeneity correlated with homicide rates of cohorts exposed during early gestation find that increased local violence seven to nine months before birth leads to statistically significantly reduced birth weight (p value of .059). This nontrivial change in the overall set of results points to the misleading conclusions that can be drawn when an analysis of crime on birth outcomes fails to control for unobserved heterogeneity between mothers/families. Moreover, the positive bias found in the early gestation exposure estimates in columns 3 and 5, driven by endogenous fertility and migration, respectively, may reflect the source of the differing findings between this analysis and that by Torche and Villarreal (2014). Similarly, column 5—which includes sibling fixed effects but assigns homicide exposure based on residence at birth, and thus does not control for the bias of endogenous migration—provides evidence that the conclusions of the analysis are significantly altered unless the behavioral response of migration is also addressed in the estimation strategy.

Using the preferred strategy of using sibling fixed effects and removing the potential for endogenous location choice, Table 4 displays results as additional controls are added to the model. As temporal and geographic controls are included in the model (columns 2–4), the magnitude of the early gestation effect only grows.[5] Even including municipality of birth fixed effects × a year of birth linear time trend—thus, a control at the municipality-time level—does not change the results. The coefficient on the

[5] As shown in Table S3 of Online Resource 1, homicide rates before conception and after birth do not have a statistically significant effect on birth outcomes. To make the coefficients comparable in Table S3, I scale all homicide results to reflect 1 homicide per 10,000 people per three-month period.

Table 3 Impact of local homicide rate on birth weight for all births since baseline and before July, 2009 to panel women in the MxFLS3 reproductive history

Homicide Rate	(1)	(2)	(3)	(4)	(5)
9–7 Months Before Birth	–0.9	27.8	–39.9	–120.3[†]	–51.6
	(34.6)	(54.5)	(37.6)	(63.1)	(70.0)
6–4 Months Before Birth	–61.5*	–39.0	–54.0	31.7	97.7*
	(30.7)	(61.7)	(34.8)	(57.3)	(47.1)
3–1 Months Before Birth	35.6	27.4	–3.4	21.8	39.2
	(32.8)	(51.0)	(55.9)	(59.9)	(82.7)
Sibling Sample	No	No	Yes	Yes	Yes
Sibling Fixed Effects	No	No	No	Yes	Yes
Municipality Fixed Effects	No	Yes	No	No	No
State–Year of Birth Time Trends	No	No	No	No	No
Pre-/Post-gestation Homicide Rates	No	Yes	No	No	No
Municipality–Year of Birth Time Trends	No	Yes	No	No	No
MxFLS1 Used as Exposure Location	Yes	Yes	Yes	Yes	No
Mean of Dependent Variable	3,241.6	3,241.6	3,249.4	3,249.4	3,245.0
Number of Observations	1,868	1,868	891	891	798
Number of Mothers				415	373

Notes: Homicide rates are per 10,000. Standard errors, clustered at the municipality level, are shown in parentheses. Regressions additionally include controls for the gender of the child, maternal characteristics (age at birth, age at birth squared, years of education, employment status, earnings per month, and marital status), household characteristics (size, per capita expenditure, and rural status), year of birth, month of birth, year of interview, month of interview, birth order, and survey wave fixed effects.

[†]$p < .10$; $*p < .05$

variable *nine to seven months* remains close to statistically significant at the 5 % level (p value of .053) and larger (–344.1), whereas the other homicide coefficients move closer to 0 and remain nonsignificant. Although the results of the specification in column 4 only further support the hypothesis that conflict exposure in early gestation has an adverse impact on birth outcomes, the size of the result should be taken with caution given the limited variation remaining to calculate it. With this fact in mind, the more conservative state linear time trend model in column 3 is the preferred specification used in the remaining analysis of this article. All analyses reported in the following tables are qualitatively similar, with larger effect sizes and less precision when municipality time trends are used.

To give some guidance to interpreting the results, the average homicide rate in Mexico between the preescalation of violence period 2005–2007 and 2009 rose by approximately 1 homicide per 10,000 in MxFLS1 municipalities, which would produce a rise of approximately 0.25 homicides per 10,000 in the three-month homicide rate. Thus, the results from the preferred specification in column 3 of Table 4 predict that the loss in birth weight resulting from the average three-month increase in violence in Mexico between the preconflict period and 2009 during early gestation is 62.5g (250 × 0.25). An alternative way to conceptualize the estimates is to calculate the impact on birth weight of one additional homicide in a representative municipality. The median

Table 4 Impact of local homicide rate on birth weight for all births since baseline and before July, 2009 to panel women in the MxFLS3 reproductive history

Homicide Rate	(1)	(2)	(3)	(4)
9–7 Months Before Birth	–120.3†	–220.6*	–250.2*	–344.1†
	(63.1)	(110.1)	(103.0)	(175.7)
6–4 Months Before Birth	31.7	67.0	55.7	–27.6
	(57.3)	(84.0)	(86.4)	(157.8)
3–1 Months Before Birth	21.8	143.1	79.8	69.4
	(59.9)	(97.8)	(83.2)	(150.6)
Sibling Sample	Yes	Yes	Yes	Yes
Sibling Fixed Effects	Yes	Yes	Yes	Yes
Municipality Fixed Effects	No	Yes	Yes	Yes
State–Year of Birth Time Trends	No	Yes	Yes	No
Pre-/Post-gestation Homicide Rates	No	No	Yes	Yes
Municipality–Year of Birth Time Trends	No	No	No	Yes
MxFLS1 Used as Exposure Location	Yes	Yes	Yes	Yes
Mean of Dependent Variable	3,249.4	3,249.4	3,249.4	3,249.4
Number of Observations	891	891	891	891
Number of Mothers	415	415	415	415

Notes: Homicide rates are per 10,000. Standard errors, clustered at the municipality level, are shown in parentheses. Regressions additionally include controls for the gender of the child, maternal characteristics (age at birth, age at birth squared, years of education, employment status, earnings per month, and marital status), household characteristics (size, per capita expenditure, and rural status), year of birth, month of birth, year of interview, month of interview, birth order, and survey wave fixed effects.

† $p < .10$; * $p < .05$

2009 population among MxFLS1 municipalities is approximately 60,000 people. Thus, according to estimates in column 3 of Table 4, one extra homicide during early gestation in a municipality of this size would generate a 42g decrease in birth weight among the exposed.

One potential general concern with these findings is that they are based on self-reported birth weight. A strength of the empirical approach is that if measurement error in birth weight is mother-specific or determined by a fixed characteristic of the mother, it is swept out by the mother fixed effect. Moreover, if the measurement error is random within a mother, it will not bias the estimates but rather make them less precise. Alternatively, if within the same mother, exposure to violence causes the mother to consistently underestimate the exposed child's birth weight as compared with the unexposed child, this would be a threat to the internal validity of the results. Although direct evidence against this possibility cannot be provided, I test whether mothers are more likely to report a rounded/stacked birth weight (e.g., a birth weight ending in 0.0 or 0.5 kg) for children exposed to more violence *in utero*. This analysis, shown in Table S4 (Online Resource 1), finds no statistically significant relationship between violence exposure and stacking behavior.

An additional set of analyses, which explores heterogeneity in the size of the effect across family types, is presented in Table S5 (Online Resource 1). These results provide evidence that the birth weight of children with mothers of lower socioeconomic status (SES) and poorer self-reported mental health is more sensitive to local violence exposure early in gestation.

To provide more information about how local conflict affects birth outcomes, I analyze the probability of a birth falling into one of the clinically used categories of poor fetal health—namely, LBW (<2,500g); see Table 5. Because of stacking at 2,500g in the data, column 1 presents the results when those listed as weighing exactly 2,500g are also included as LBW, and column 3 considers a child LBW only if the birth weight is strictly less than 2,500g. Although the early gestation coefficient is imprecisely estimated, its sign and magnitude in column 1 provide suggestive evidence that exposure to greater local violence in the first few months of pregnancy is associated with an increased likelihood of having a child that weighs 2,500g or less (p value = .14). Moreover, when examining a group of mothers at higher risk of having a LBW child (e.g., mothers of lower SES), I find that an increase in exposure to violence in early gestation statistically significantly elevates the probability of being born with LBW (see columns 2 and 4). Specifically, these results suggest that in median-sized Mexican municipalities, exposure to one additional homicide in early gestation for children of lower-SES families increases the probability of low birth weight by between 2.5 and 5 percentage points.[6]

In summary, children born to mothers exposed in early gestation to the recent surge in conflict caused by the Mexican Drug War are suffering from substantial and statistically significant reductions in birth weight.

Relative Size of the Effect

The analysis presented in this article provides evidence that exposure to local violence in early pregnancy leads to a reduction in birth weight. Having a sense of the relative size of this effect, though, is of great importance because it provides guidance for determining the severity of this concealed cost of crime and conflict.

The results suggest that one additional homicide in the average sized Mexican municipality during early gestation led to a 42g reduction in birth weight.[7] One way to evaluate the magnitude of the effect of the Mexican Drug War on fetal health is to compare its adverse impact against the gains achieved in Mexico by a government social assistance program designed to improve birth outcomes of participating women.

[6] I also use macrosomia (4,000g and >4,000g) as an independent variable in the main specification, and results provide no evidence that exposure to violence *in utero* has a relationship with this birth outcome.

[7] Comparing this result with the findings in Mansour and Rees (2012), the magnitude is similar in size (33g) to the decrease in birth weight predicted from experiencing the average first trimester increase in fatalities in the al-Aqsa Intifada. Alternative estimates of the early gestation effect of living in a conflict region would suggest an additional municipal homicide in Mexico has an effect on birth weight that is five times larger (9g) than having a landmine explode in the mother's municipality of residence in Colombia from 1998–2003 (Camacho 2008) and three times larger (15g) than living in a region of Israel hit by a missile during the 2006 Israel-Hezbollah War (Torche and Shwed 2015). Looking at environmental shocks unrelated to violence, I find that the impact of one additional municipal homicide in early gestation on birth weight is similar in size (51g) to experiencing high-intensity exposure to the 2005 Tarapaca earthquake in Chile in the first trimester (Torche 2011) and approximately double the size (21g) of having a mother's parent die while *in utero* (Black et al. 2016).

Table 5 Impact of local homicide rate on the probability of low birth weight for all births since baseline and before July 2009

Homicide Rate	LBW+ (≤2,500g) All (1)	LBW+ (≤2,500g) Bottom 50 % of Per Capita Expenditure (2)	LBW (<2,500g) All (3)	LBW (<2,500g) Bottom 50 % of Per Capita Expenditure (4)
9–7 Months Before Birth (%)	11.0	31.5**	3.3	15.4†
	(7.3)	(11.3)	(3.2)	(8.0)
6–4 Months Before Birth (%)	–6.3	–9.0	–5.0	–3.6
	(5.5)	(8.5)	(3.8)	(8.0)
3–1 Months Before Birth (%)	–0.6	1.9	–3.8	–12.5
	(6.7)	(12.7)	(3.4)	(9.0)
Sibling Sample	Yes	Yes	Yes	Yes
Sibling Fixed Effects	Yes	Yes	Yes	Yes
Municipality Fixed Effects	Yes	Yes	Yes	Yes
State–Year of Birth Time Trends	Yes	Yes	Yes	Yes
Pre-/Post-gestation Homicide Rates	Yes	Yes	Yes	Yes
MxFLS1 Used as Exposure Location	Yes	Yes	Yes	Yes
Mean of Dependent Variable (%)	10.7	12.5	7.1	7.9
Number of Observations	891	432	891	432
Number of Mothers	415	203	415	203

Notes: Homicide rates are per 10,000. Standard errors, clustered at the municipality level, are shown in parentheses. Stratifications based on MxFLS1 maternal characteristics. Regressions also include all additional controls used in Table 4.

†$p < .10$; **$p < .10$

Oportunidades (formerly, *PROGRESA*) is a large-scale conditional cash transfer (CCT) program in Mexico targeting poorer families and tying compensation to investment in the education and health of the household's children. One component of the program is that pregnant women must complete a prearranged prenatal care plan, acquire specific nutritional supplements, and attend meetings that focus on pregnancy health education (Barber and Gertler 2008). Evaluation of the impact this program had on the birth outcomes of participating mothers suggested that the children exposed to *Oportunidades* while *in utero* were born 127g heavier (Barber and Gertler 2008). This estimate suggests that the recent conflict in Mexico could be eliminating approximately one-third of the gains of one of the oldest and largest CCTs in existence.

An additional way to provide perspective on the magnitude of the adverse impact of the Mexican Drug War on fetal health is to compare its effect with commonly cited drivers of birth outcomes, such as nutrition. Hoynes et al. (2011) and Almond et al. (2011) evaluated the U.S. programs Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and the Food Stamp Program (FSP; now referred to as Supplemental Nutrition Assistance Program, or SNAP), respectively, in terms of their positive effect on birth). Hoynes et al. estimated a 2g birth weight effect of WIC on the average population and a 18g to 29g impact among participants, and Almond et al. found that that FSP participation led to birth weight increases of 2g to 5g in general and 15g to 40g among the treated.

Mechanisms

A final aspect of these findings that needs to be explored is the relative importance of each potential pathway driving the relationship between local violence and birth outcomes. The literature suggests that poorer health behaviors (e.g., smoking, less exercise), decreased use of health care, constrained nutrient intake, and the mother's biological reaction to anxiety are the main avenues.

The rich individual-level information of the MxFLS provides some insight into the first two channels: health behaviors and health care use. Using an individual fixed-effects model, I analyze whether the level of violence exposure in the year leading up to the MxFLS2 and MxFLS3 interviews caused a change in the sample mothers' self-reported health behaviors (exercise and smoking). I use the quartic root of each measure as a proxy for the log transformation because the log transformation would drop observations with a value of 0 and the quartic root behaves similarly to a logarithmic transformation for positive numbers. The results of this analysis, provided in Table S6 (Online Resource 1), strongly suggest that local violence exposure for the sample of interest did not adversely affect these types of health behaviors.

In addition, the impact of violence exposure on the number and timing of a mother's prenatal care visits during each pregnancy can be examined. Table S7 (Online Resource 1) presents the results of using the number of prenatal care visits and the probability of initiating prenatal care in the first two months of pregnancy as the dependent variable in Eq. (2). These estimates suggest that although the average increase in violence exposure early in gestation is not significantly related to fewer overall prenatal care visits, it is associated with an increase of approximately 4 percentage points in the probability of delaying prenatal care initiation. While these results provide suggestive evidence of an important behavioral response to local violence exposure, they do not seem to be the primary mechanism driving the main results given that the inclusion of both of the prenatal care measures as independent variables in Eq. (2) only minimally (10 %) attenuates the main results from Table 4, column 3 (see Table S8, Online Resource 1).

Another potential mechanism for the relationship between *in utero* violence exposure and fetal health is reduced nutrition. One reason to doubt that this is the main channel at work in this context is the fact that the effect of exposure to the Mexican conflict is concentrated in the first trimester. This timing does not match the findings from Almond and Mazumder (2011) on the relationship between restricted consumption during pregnancy and birth weight. Moreover, the effect size estimated by Almond and Mazumder—as well as the various aforementioned studies of nutrition programs, such as WIC (2g to 5g) and FSP (2g to 5g)—is significantly smaller than those found in this study. Given that those studies focused directly on nutrition and found much smaller effects, it is unlikely that potential nutrient restriction from Mexican Drug War exposure is the leading mechanism resulting in the large negative estimates shown in this study.

The last plausible mechanism remaining to account for the relationship found in this study is fetal exposure to the mother's biological response to anxiety. The timing of the effect estimated in this study (early gestation) matches the findings from the social science literature on the impact of maternal mental distress on fetal health (Brown 2014; Camacho 2008; Mansour and Rees 2012; Torche 2011; Torche and Shwed 2015).

One unique advantage of this study is that by using the mental health portion of the MxFLS and the panel nature of the survey, I can estimate an individual fixed-effects model to test whether being exposed to an increased homicide rate is predictive of the self-reported emotional well-being of the mothers used in the analytical sample. The dependent variables explored in these analyses are a mental health index, a proxy for the log transformation of the mental health index (the quartic root), and an indicator for receiving a perfect score on the mental health index. The results of this analysis, shown in Table S9 (Online Resource 1), provide suggestive evidence that in the case of the recent outbreak of violence in Mexico, mothers living in a municipality that experienced an increase in the homicide rate reported poorer emotional well-being.

The rich set of information available in the Mexican Family Life Survey and the timing of its data collection allow a rare opportunity to investigate the mechanisms driving the relationship between maternal exposure to violent conflict and birth outcomes. The results show that neither prenatal nor general health behavior changes can explain the poor birth outcomes associated with rising local conflict. Additionally, the predicted effect—if the nutrition channel was the driving force—does not match the magnitude or timing of the results presented in this article.

This leaves biological response to maternal anxiety as the most likely remaining pathway. Supporting this hypothesis is the fact that the period of sensitivity to violence presented herein coincides with the estimates from studies that have focused on the impact of maternal anxiety on birth outcomes. Moreover, this study is uniquely able to present even stronger reinforcement for this mechanism by providing evidence that living in a violent neighborhood in Mexico does hinder the self-reported emotional well-being of the affected mothers.

Although a plausible mechanism can be established in this case, one unexplored aspect of this maternal anxiety pathway is the particular biological response creating this link. Specifically, because the data used in this study cannot distinguish between an effect on intrauterine growth versus gestational duration and because gestation period biomarkers are not available, this study cannot address the relative importance of CRH production, stress-induced blood flow restrictions, and immune system/inflammation in this relationship.

Conclusion

The recent escalation of the Mexican Drug War has cost the country thousands of lives and disseminated a widespread sense of insecurity amongst the noncombatants. Existing research has already documented some of the explicit adverse effects of the violence, such as increased victimization (extortions, kidnappings), losses of earnings and employment, and reduced human capital accumulation (Brown and Velásquez 2017; Guerrero-Gutiérrez 2011; Molzahn et al. 2012; Velásquez 2015). Alternatively, other recent work has claimed some positive externalities to the violence. Specifically, they found that mothers exposed to the elevated violence in Mexico during pregnancy have as a response taken on more pro-health behaviors, resulting in better birth outcomes (Torche and Villarreal, 2014).

The analysis in this study challenges this result and provides evidence that bias inducing endogenous behavioral response by the affected mothers is present in the context of the recent violence in Mexico. In concordance with the prior estimates of the effect of the Mexican Drug War on birth weight, when using a model controlling only fixed temporal and geographic heterogeneity, it appears that early gestation exposure to violent crime has a positive relationship with birth weight. The insight herein is that a positive early gestation selection bias in the composition of mothers willing and able to bring a child to term after intense exposure to violent crime and a nonrandom migration response to local violence exist in this setting. With these findings motivating the empirical strategy, the estimates of an improved econometric model documents that after accounting for migration and unobserved heterogeneity between mothers, an increase in local violence in early gestation leads to a large and significant decrease in birth weight.

These findings add to a growing literature documenting the adverse effects of living in a violent location early in life on the acquisition of human capital in general (Akresh et al. 2012a, 2012b; Sharkey 2010) and fetal health specifically (Camacho 2008; Mansour and Rees 2012; Torche and Shwed 2015). In addition, using the wealth of detailed individual- and family-level information in the Mexican Family Life Survey allows for a unique opportunity to examine many of the potential mechanisms linking prenatal exposure to violent crime and birth outcomes. This analysis provides suggestive evidence that the biological reaction to increased anxiety is the most important channel.

Viewed in conjunction with the findings in the broader literature, this study implies that the costs of internal conflict and violent crime must account for its potential impact on the well-being of the next generation.

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