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Prenatal exposure to violence and birth weight in Mexico: Selectivity, exposure, and behavioral responses

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1. Introduction

Violence is a social problem with enormous direct costs in terms of death tolls, injuries, disabilities, and loss of property (Krug, Mercy, Dahlberg, and Zwi 2002; Miller, Cohen, and Rossman 1993). Moreover, the effects of violence can extend far beyond its immediate victims: Research suggests that witnessing violence in one's surroundings may have severe health consequences, driven by stress and anxiety, even among those who are not direct victims. Much less is known about the effect of maternal exposure to violence during the prenatal period. This is a serious limitation, because we now know that the intra-uterine period is sensitive to the environment experienced by the mother, and that prenatal exposures have profound consequences over the entire life course (Almond and Currie 2011; Palloni 2006).

This paper addresses this question by examining the effect of prenatal exposure to local homicides on birthweight in Mexico. We focus on birthweight because it is a powerful measure of individual resources at the “starting gate” of life. Low birth weight identifies infants most at risk of mortality, morbidity and developmental problems (Kline, Stein, and Susser 1989; Paneth 1995), and it has consequences for later health, development, and wellbeing (Conley, Strully, and Bennett 2003). The phenomenon studied has implications well beyond the Mexican case. Exposure to violence –and to its most extreme form, homicide– is unfortunately prevalent in the lives of many people, particularly the more disadvantaged (Evans and Kantrowitz 2002). A growing literature on neighborhood effects examines the effect of local-level violence on birth outcomes (Harding 2009; Masi, Hawkey, Piotrowski, and Pickett 2007; Moiduddin and Massey 2008; Morenoff 2003; OCampo, Xue, Wang, and Caughy 1997; Zapata, Rebolledo, Atalah, Newman, and King 1992). A perennial concern in this literature, however, is that of unobserved selectivity. Is it the actual violence or unmeasured factors correlated with both violence and birthweight that cause the observed effect? This question prevents researchers from moving from observing an association to establishing causality.

Recent research has resorted to “natural experiments” to address unobserved selectivity. Natural experiments are events that occur in the physical or social world, which are allocated at “as random” within a particular population, for example a sudden economic

decline, a natural disaster, or a drastic change in social policy. Because they occur at “as random,” natural experiments are considered exogenous, in that exposure is not correlated with unobserved maternal or local characteristics. However, in their zeal to assert causality, research based on natural experiments may neglect that exposures of interest usually induce preemptive or adaptive responses among the population, thus missing an important part of the answer.

This is the case of violence. Violence is a serious environmental risk and people react to it with a range of responses in order to avoid exposure or reduce its negative consequences. Among pregnant women, responses such as migration, fertility adjustments, and behavioral changes intended to reduce harm (or simply reduce anxiety) may be expected. These responses may affect the outcome observed by altering the population of live births at risk of exposure (migration and fertility adjustments), or by mediating the effect of exposure to violence on birth outcomes (behavioral changes such as dietary changes, smoking, or use of prenatal care). For example, growing neighborhood violence may induce women to postpone fertility. If this response is heterogeneous, it will alter the population at risk of live birth. For instance, highly-educated women may be more likely to reduce fertility if they can implement birth control techniques more efficiently (Pop-Eleches 2010). To the extent that babies born to educated women have higher birthweight, their fertility reduction will induce negative selectivity of observed births. If researchers do not account for changes in fertility, they will observe a decline in birthweight that they will mistakenly attribute to violence instead of to the compositional change in the population of newborns. Alternatively, the stress and anxiety induced by neighborhood violence may lead to worsened nutrition among pregnant women (Margerison-Zilko, Catalano, Hubbard, and Ahern 2011). Given that nutrition shapes birth outcomes, this will have an indirect effect on birthweight, mediated by behavioral changes.

In this article, we examine the effect of prenatal exposure to violence while also considering preemptive and adaptive responses by pregnant women at the population level. To do so, we exploit monthly changes in homicides at the municipal level in Mexico between 2007 and 2010. At the national level, the homicide rate grew by more than 100% over this period, according to information obtained from vital statistics records, and a close to 90% increase according to criminal statistics (Figure 1). The increase is largely attributed to the escalation of violence caused by Drug Trafficking Organizations (DTOs). According to the best available estimates, the number of homicides attributable to the drug trade grew more than five-fold in the country as a whole, from 2,826 in 2007 to 15,273 in 2010 (Rios and Shirk 2012).

The increase in drug trafficking-related violence is puzzling considering that Mexico has been a hub for drug traffic into the U.S. since at least the early twentieth century, and that DTOs have existed for decades (Beittel 2012). Analysts suggest that the growth and entrenchment of Mexico’s drug trafficking networks occurred during a period of one-party rule by the PRI, which governed Mexico between 1929 and 2000. During the PRI rule, the government was centralized and hierarchical, and it tolerated some drug production and trafficking in certain regions of the country. The relative stability in the relationship between the state, drug enforcement, and DTOs began to fray when power decentralized and the PRI

lost important local and state elections in the 1990s, and the presidency in 2000 (Astorga and Shirk 2010). At the same time, the traffic of illegal drugs to the United States from Mexico increased and became more lucrative with the weakening of the Colombian cartels and the closing of traffic routes through the Caribbean (Brands 2009; Beittel 2012).

The 2006 election was a watershed moment in drug enforcement policy, as the newly elected president Felipe Calderón launched an unprecedented crackdown on drug trafficking. Given the widespread corruption of federal, state and local police forces, the Calderón administration increasingly relied on the military to combat DTOs (Daly, Heinle and Shirk 2012). Troop numbers and military budgets rose steadily during this period. The Mexican government's tough approach resulted in many high-profile arrests and killings of DTO leaders (Gonzalez 2009). However, the militarization of the conflict also led to charges of human rights violations by the Mexican armed forces (Amnesty International 2009; Daly, Heinle and Shirk 2012).

An unintended consequence of the Mexican government's arrests and killings of top DTO leaders was the fragmentation, splintering and infighting among and within drug trade organizations (Guerrero 2011; O'Neil 2011). The capture of drug leaders shook cartel structures, triggering disputes over succession and opportunistic behavior by rival organizations for coveted trafficking routes, thereby tightening the competition for power among and within the increasingly fragmented organizations (Sabet and Rios 2009; Shirk 2010). These developments appear to have resulted in an unprecedented increase in homicides and other forms of violence, initially targeted at drug traffickers, but increasingly affecting government authorities, law enforcement personnel, journalists, and bystanders.

The fragmentation of the DTOs was accompanied by diversification into other criminal activities –including extortion, kidnapping, and bank and car robberies (Beittel 2012; Guerrero 2011), as well as by growing geographical dispersion. Initially, violence was concentrated in a few cities and states, the traditional drug-trafficking routes (Shirk 2010). But since 2009, violence has dispersed to new areas and involved previously untouched municipalities (Beittel 2012). By 2011 it had affected 84% of Mexican municipalities (Molzahn, Rios, and Shirk 2012).

There are several reasons why violence perpetrated by DTOs may have had a profound effect on Mexicans' fear of crime despite the objectively low risk of homicide victimization for the general population. The diversification of the criminal activities of DTOs, and their geographical expansion likely exacerbated the sense of vulnerability among the population. Because drug-related violence is intended to intimidate and claim control over a territory, crimes are particularly gruesome, including use of torture, beheading and mutilation; hanging of corpses; and the writing of messages on the victim's bodies– all of which likely leaves a lasting impression on local residents (Gonzalez 2009).

Research on public reactions to crime has shown that there is greater diffusion of information regarding criminal victimization as the seriousness of the crime increases (Warr 1994). Furthermore, individuals tend to overestimate the risk of rare lethal crimes such as drug-related homicides while underestimating the risk of more common crimes (Warr 2000).

The literature also shows that information about victimization can spread quickly by word of mouth and can be magnified by the media's portraits of the randomness and normalness of the attacks (Box, Hale, and Andrews 1988; Gerbner, Gross, and Signorielli 1986). This is indeed the case in Mexico, where the media offers intense coverage and vivid depictions of the drug-related violence (Casas-Perez 2011). The available evidence suggests that the recent increase in violence has indeed led to a generalized feeling of insecurity. According to the National Survey of Insecurity (*Encuesta Nacional Sobre Inseguridad ENSI*) the percentage of Mexicans who think the state they live in is insecure rose from 54.2% in 2004 to 65.1% in 2009. The only study examining the psychological effects of homicides in Mexico that we are aware of found a substantial increase in anxiety and depression associated with local homicide rates in Mexico (Michaelsen 2012).

Our strategy to assess the causal influence of violence on birthweight exploits the change in homicides over time and across municipalities in Mexico. In contrast to the neighborhood effects literature, our focus is not the cross-sectional variation in levels of violence at the local level, but rather the effect of pregnant women's exposure to variation in the homicide rate in their immediate environment. We create a monthly panel of births by municipality in Mexico from 2008 to 2010, with which we merge information on all homicides for the same period. Municipality-fixed effects account for potential spuriousness emerging from any time-invariant characteristics of municipalities (including the "baseline" level of violence at the local level, poverty, quality of the health care system, and environmental pollution, among others). Month fixed effects account for spuriousness emerging from any national-level trends shared across municipalities (for example, national economic or violence trends and cyclical effects emerging from the seasonality of birthweight (e.g. Torche and Corvalan 2010)). The availability of monthly homicide data allows us to exploit month-by-month departures from a "municipal average" in both crime and birthweight to identify the effect of violence by using fixed effects models. Such short-term local variation is likely uncorrelated with unobserved local characteristics shaping birth outcomes, and is likely to have important repercussions for maternal stress and women's behavioral and reproductive choices. Furthermore, we control for economic trends that the literature suggest may be driving a spurious correlation between violence and birthweight: The state-level unemployment rate, wage levels, and female labor force participation (Abadie and Gardeazabal 2003; Raphael and Winter-Ebmer 2001). We also use spatially-lagged homicide rates to account for the fact that the effect of violence is not necessarily circumscribed to municipal boundaries, and may extend to a wider spatial context.

These methodological strategies reduce the possibility of bias but they do not account for the behavioral adaptations that pregnant women may undertake in a context of growing violence. Thus, we explicitly examine plausible responses –migration, changes in fertility, and behavioral responses to violence once the woman has become pregnant– and analyze their role in shaping the population exposed to violence and in mediating the effect of violence. As a final step, we account for the fact that both the effect of violence and the behavioral responses to it may be heterogeneous across socioeconomic status, and examine such heterogeneity. We proceed as follows: The next section integrates diverse literatures to account for the effect of local homicides on birth outcomes, and for the behavioral responses

that could shape the population at risk of live birth or mediate the effect of violence exposure. Section 3 introduces the data, research questions, and analytical strategy. Section 4 offers the main findings, and section 5 presents the conclusion and discussion.

2. Exposure to violence, behavioral responses, and birth outcomes

The neighborhood effects literature shows that local violence is a powerful predictor of birth and other health outcomes. Research suggests that the violent crime rate at the local level accounts for most of the negative association between neighborhood disadvantage and birth weight (Morenoff 2003), in particular by affecting fetal growth (Masi, Hawkley, Piotrowski, and Pickett 2007). However, this literature exploits cross-sectional variation in violent crime rates across neighborhoods, which makes it difficult to disentangle the effect of violence from its unfortunately usual correlates.

Exposure to local homicides has been shown to have a direct effect on those exposed. Recent research using causal inference techniques has found that exposure to violence affects mental wellbeing (Cornaglia and Leigh 2011; Michaelsen 2012), increases the chances of perpetuating violence among youth (Bingenheimer, Brennan, and Earls 2005), and temporally reduces cognitive performance among children, even if the violence is not directly witnessed (Sharkey 2010). A likely mechanism for these effects is the increase in stress and anxiety elicited by violence exposure (Crofford 2007; Singer, Anglin, and Lunghofer 1995).

Little is known about the effect of exposure to local violence before birth. However, growing evidence from medical and psychological fields suggests that exposure to acute stress during pregnancy is harmful for the developing fetus. The mechanism is physio-endocrine. The response to a stressor triggers the production of corticotrophin releasing hormone (CRH), adrenocorticotrophic hormone (ACTH) and cortisol in both the mother and the fetus. High levels of these stress-hormones, in turn, result in reduced gestational age and low birth weight (Hobel and Culhane 2003; Lockwood 1999). It appears that the effect of stress is most detrimental when it occurs in early pregnancy, when exposure sets a clock for early delivery (Glynn, Wadhwa, Dunkel-Schetter, Chicz-DeMet, and Sandman 2001). Furthermore, stress appears to affect birthweight by reducing gestational age rather than by inducing fetal growth restriction, but the evidence about the specific mechanism is not conclusive, with some research indicating an effect on fetal growth (Wadhwa, Garite, Porto, Glynn, Chicz-DeMet, Dunkel-Schetter, and Sandman 2004). Most research has found a negative impact of prenatal stress—driven by economic contraction (Margerison-Zilko, Catalano, Hubbard, and Ahern 2011), natural disaster (Torche 2011), terrorist attack (Eskenazi, Marks, Catalano, Bruckner, and Toniolo 2007) or collective mourning (Catalano and Hartig 2001)—on birth outcomes.

It is plausible, then, that exposure to local homicides affects birth outcomes directly, driven by the heightened stress and anxiety among pregnant women. But exposure to violence could also induce behavioral adaptations to avoid or reduce risk. Two likely responses are migration and fertility adjustments. If the migration or fertility responses are heterogeneous across the population, they may induce selectivity by altering the composition of those at

risk of live births in a particular locality. For example, if high-SES women have, on average, healthy babies, and they are more likely to respond to violence by leaving the area, then selective out-migration will lead the researcher to incorrectly attribute a negative effect to homicide exposure. The available evidence suggests that fertility responses to adverse events such as economic downturns may indeed be selective, although the direction is not clear. For example, Dehejia and Lleras-Muney (2004) found that when unemployment rises, black mothers tend to be of higher socioeconomic status while white mothers are less educated.

Research about migration is also inconclusive. Studies suggest that generalized conflict such as armed civil wars (Ibanez and Velez 2008; Moore and Shellman 2004; Schmeidl 1997) and widespread racial violence (Tolnay and Beck 1992) may give rise to forced migration in some contexts. However, perceptions of neighborhood crime do not appear to be a strong or consistent predictor of actual residential mobility (South and Messner 2000). Research about selectivity of migration is scarce, with some evidence suggesting migration as a result of violence is more likely among those who are younger, and have low education and fewer economic opportunities (Engel and Ibanez 2007; Ibanez and Velez 2008).

Responses to environmental violence also include adaptive reactions to the stressful environment after the pregnancy has been established. Maternal stress may induce changes in sleep, diet, or behaviors such as smoking or drinking, which may be detrimental for the fetus (Dancause, Laplante, Oremus, Brunet, and King 2011; Margerison-Zilko, Catalano, Hubbard, and Ahern 2011). But it could also induce health-enhancing behaviors such as improved nutrition or prenatal care utilization—for example, research has found women exposed to a hurricane in the first trimester of gestation were less likely to gain excessive weight or to have inadequate prenatal care (Currie and Rossin-Slater 2012).

How can we account for these diverging responses? Under which circumstances is maternal stress likely to induce health-enhancing versus health-depressing responses? Psychological theory provides an answer by proposing an inverted U-shaped relationship between perceived risk and performance—the so-called Yerkes-Dodson (1908) hypothesis. According to this formulation, low levels of perceived risk do not provide sufficient motivation to act effectively, while moderate level of risk provide sufficient motivation to engage in health-enhancing behaviors without preventing the ability to respond to the environmental risk. If, however, perceived risk reaches high levels, defensive mechanisms will be targeted at reducing anxiety—usually by engaging in unhealthy behaviors—rather than at addressing the threat (Anderson 1976).

Thus, the local increase in homicides may have induced health-depressing behaviors or health-enhancing behaviors among pregnant women, depending on the level of perceived risk. The fear of crime literature suggests that health-enhancing responses intended to reduce harm should be stronger when the likelihood or severity of harm due to environmental exposures is perceived to be higher (Brewer, Chapman, Gibbons, Gerrard, McCaul, and Weinstein 2007; Garofalo 1981). In particular, anticipated worry and regret about not having acted are strong predictors of behavioral responses as shown, for example, in vaccination-uptake studies (Chapman and Coups 2006; Weinstein, Kwitel, McCaul, Magnan, Gerrard,

and Gibbons 2007). Responses intended to avoid or reduce risk are likely to be strong among pregnant women if, as suggested by the literature, “altruistic fear” for their unborn child is more intense than personal fear (Warr 2000).

We use information on prenatal care to assess pregnant women’s behavioral responses to variation in local homicides. Because there is little variation in prenatal care utilization in Mexico (97% of women receive care), we will also rely on time of care initiation and number of prenatal care visits, which are the standard measures of prenatal care adequacy (Kotelchuck 1994). Research in the industrialized world has shown a positive effect of prenatal care on birth outcomes, after taking into account self-selection into care (Conway and Deb 2005; Grossman and Joyce 1990; Liu 1998; Rosenzweig and Schultz 1982; Rous, Jewell, and Brown 2004). The few studies of prenatal care utilization effects that account for maternal self-selection into care in Latin America suggest that the beneficial effect of prenatal care may be stronger than in the industrialized world (Frank, Pelcastre, de Snyder, Frisbie, Potter, and Bronfman-Pertzovsky 2004; Jewell 2007; Wehby, Murray, Castilla, Lopez-Camelo, and Ohsfeldt 2009b; Wehby, Murray, Castilla, Lopez-Camelo, and Ohsfeldt 2009c)). The mechanisms for this positive effect include reduction in maternal smoking, provision of information about nutrition and adequate self-care, and management of co-morbidities.

We investigate whether exposure to violence may alter the use of prenatal care, thereby affecting birth outcomes. We hypothesize that women may respond to the increase in local violence by altering their use of prenatal care, and that such response may be heterogeneous. For example, women who feel they are more vulnerable to violence or those who are more conscientious may be more likely to increase their use of prenatal care. Note that independently from exposure to local violence, some women may self-select into more prenatal care too (if they, for instance, have previous morbidities). Given our analytical strategy, self-selection that is *not* correlated to violence will not bias our results. The effect we identify captures the association between changes in the homicide rate and in the use of prenatal care at the local level. As a result, determinants of prenatal care use that are orthogonal to homicide exposure do not affect our estimators.

In sum, we integrate insights from diverse literatures –neighborhood effects, fear of crime, medical and psychological research on maternal stress and birth outcomes, demographic studies of population responses to adverse exposures, and cognitive psychology– to offer plausible mechanisms for the effect of homicide exposure on birth outcomes including a direct effect and behavioral responses that may alter the population at risk of live birth or mediate the influence of violence exposure.

3. Data, research questions, and analytical strategy

Data

Our main data source is the complete file of Mexican birth certificates for the period January 2008 – December 2010, which comprises approximately 2 million births per year. Birth certificates includes information about the newborn (date of delivery, gestational age, weight, etc.) and about the mother (age, education, number of times the woman has given

birth [parity], etc.). Crucially for our analysis, the certificate includes information about the municipality of habitual residence of the mother, with approximately 2,500 municipalities in Mexico. Given that the publicly available data includes the newborn's weight only since 2008, our analysis was limited to all births occurring between January, 2008 and December, 2010, the most recent month for which data are currently available. Because multiple births are significantly lower-weight, we restrict the analysis to singletons, which represent 98.4% of total births.

We merge birth records with the homicide database based on the municipality of habitual residence of the mother to create a 36-month panel of individual births as explained below. Information regarding the number of homicides is obtained from vital statistics. The Mexican National Institute for Statistics and Geography (INEGI) compiles basic information on all fatalities occurring in the country, including the municipality of occurrence and the cause of death based on the World Health Organization's guidelines (ICD-10) (INEGI 2003). Vital statistics are the best source of information to estimate homicide rates in Mexican municipalities because, unlike estimates based on reported offenses by prosecutors' offices, they are not affected by state-level differences in the legal definition of homicide or biases in the reporting of offenses.

Alternatively, we could have used statistics about homicides presumably related to organized crime compiled by Mexican agencies. We choose to use vital statistics given the difficulty, in some instances, of ascertaining which homicides are related to organized crime, which likely results in underestimation. However, we replicate our analysis using a database prepared by the National Public Security System with the total number of homicides from organized crime.¹ The results from this ancillary analysis closely replicate the findings reported below.

We calculate the homicide rate per thousand residents for each municipality where the mother resided during her pregnancy by dividing the total number of deaths due to homicide registered in a given trimester by the estimate of the municipal population for that year obtained from the Mexican National Population Council (CONAPO 2006). Mexican municipalities vary widely in population size. For example, the Riva Palacio municipality in the northern state of Chihuahua has a population of 7,395, while the population in the contiguous municipality of Cuauhtémoc is 137,534. To the extent that the mechanism inducing stress depends on the geographical and social distance to the homicide, it is more likely that women in Riva Palacio have direct or indirect knowledge of any single homicide, and thus are more affected by a homicide in their municipality than women in Cuauhtémoc are affected by a homicide in their municipality. An adjustment for population accounts for the fact that homicide rate—rather than homicide count—may better proxy the impact of homicides on the population. Naturally, this is just an approximation. An optimal strategy would require geocoding the exact location of each homicide and of the maternal residence or to use smaller geographical units such as neighborhoods, which is prevented by data availability in this national-level study. However, if the effect of homicide exposure does indeed depend on proximity, then the effect detected would be stronger if we were able to

¹Information available online at <http://www.presidencia.gob.mx/base-de-datos-de-fallecimientos/>.

measure at a smaller geographical level. In this sense, our estimates provide a lower-bound assessment of the effect that would be captured if neighborhood-level data was available. We examine alternative formulations of homicide exposure (including simple counts) in the robustness checks section.

Research questions

Our main focus is the effect of exposure to local homicides on birth outcomes in Mexico. Because the population at risk of live birth in a particular municipality is shaped by women's decisions about fertility and migration, we first examine the effect of local homicides on the birth rate and the migration rate. Given that fertility and migration responses may be heterogeneous across the population—creating a selected sample at risk of live birth—our second question is, does the effect of homicide exposure on fertility and migration vary across the socioeconomic characteristics of women? Note that this question addresses selectivity based on observed characteristics, while our concern extends to unobserved attributes. If no effect is found on observed characteristics, the probability of an effect based on unobserved attributes is much decreased; as such an attribute would need to be uncorrelated not only with unobserved municipal attributes and temporal trends, but also with observed characteristics of mothers. We then move to our main question: What is the effect of acute exposure to local homicides on birth weight and on the probability of low birth weight? We also examine variation in the effect across timing of exposure—trimester of gestation—and the mechanism of the influence on birthweight—fetal growth or gestational age. We then address the question about behavioral responses—in particular, prenatal care utilization—as a potential mechanism for the effects of exposure on birth weight. Finally, we consider the question about heterogeneity of the observed effect: Does the effect of local violence vary by women's socioeconomic status?

Analytical formulation

The first question is about the relationship between exposure to homicides and fertility and migration at the municipal level. For the analysis of fertility, we create a monthly panel of municipalities and estimate equation 1:

$$BR_{jks} = \beta_0 + \beta_1 (Homicide_{jk1}) + \beta_2 (Municipality_j) + \beta_3 (Month_k) + \beta_4 (Trends_{jks}) + \varepsilon_{jk} \quad (1)$$

Where *BR* identifies the outcome of interest (birth rate) in the municipality of maternal residence *j*, month *k* and state *s*. The birth rate is operationalized as the number of births per 1,000 women aged 15–64 in municipality *j*². *Month* is an indicator for month of birth, *Municipality* identifies a set of indicator variables for municipality of mother's residence, *Homicide* represents the homicide rate in the municipality *j* for births in month *k* during period of exposure *l* and *Trends* refers to time-varying socioeconomic variables in state *s*, including unemployment rate, wage levels, and female labor force participation³. *l* refers to the two trimesters (6 months) preceding conception leading to birth in month *k*.

²Ideally we would have used the number of women of reproductive age, but information about population by gender, age, and municipality provided by the Mexican National Population Council (CONAPO) includes only the following age groupings: 0–14, 15–64, 65 and more. (Online at: http://www.conapo.gob.mx/index.php?option=com_content&view=article&id=36&Itemid=234).

Including one indicator (“fixed effect”) for each municipality and each month of birth means estimating a different intercept for each municipality and month. This is algebraically equivalent to taking the deviations from the within-municipality means over time for the dependent and independent variables and running a regression on these mean deviations (Angrist and Pischke 2009: 221–227, Firebaugh 2008: 134–145, Halaby 2004). This fixed effects model is also known as “within estimator” because by estimating a different intercept for each municipality and month of birth, it uses only over-time variation within municipality that departs from national-level over-time variation. This implies loss in efficiency but accomplishes a crucial objective in causal inference: Purging the estimators from bias resulting from unobserved heterogeneity across municipalities or months of birth.

In order to address our second question about socioeconomic heterogeneity in fertility responses to violence, we test models predicting several socioeconomic characteristics of women giving birth: Maternal education, marital status, and health insurance. *Primary* captures the proportion of women with less than 9 years of schooling (lower secondary) in municipality *j*. *Married* distinguishes married women from those with other marital statuses, and *Health Insurance* distinguishes women with any kind of formal health insurance from those without insurance. These models are identical to equation (1) except that the dependent variable identifies the proportion of mothers with each socioeconomic characteristic at the municipal level.

These models predicting the socioeconomic characteristics of mothers provide indirect evidence about different fertility responses by SES, under the assumption that the aggregate characteristics of women at risk of giving birth in a particular municipality remain relatively constant from one trimester to the next. If this assumption holds, then a change in the socioeconomic composition of women actually giving birth will indicate selective change in fertility. For example, a decrease in the proportion of women with only primary education giving birth as a result of exposure to homicides in the two trimesters preceding (potential) conception will indicate that women with low education reduced their fertility compared to highly-educated women. But the assumption that the socioeconomic composition of women at risk of giving birth is stable would be violated if there is selective inter-municipal migration as a result of an increase in crime. In order to gauge the effect of violence on migration and its potential selectivity, we tested models of municipal out-migration for women of childbearing age (15–44 years of age) using the change in municipal homicide rate as a predictor in an OLS model. Municipal out-migration rates from 2005 to 2010 are computed from the 2010 Mexican Population Census, which identifies the municipality of residence of all individuals five years prior to the date of the Census. The change in the municipal homicide rate between the two years immediately before the beginning and the end of the five-year period is used as our primary predictor. We rely on the Mexican Census for our analysis of selective migration because birth records datasets do not contain

³These variables were obtained from published tabulations of the Mexican National Occupation and Employment Survey (*Encuesta Nacional de Ocupación y Empleo, ENOE*). Because the survey is representative at the state level, our measures are calculated for each state. The unemployment rate is measured on a monthly basis, while wage levels and female labor force participation rates are calculated quarterly.

women's migratory experience. This strategy is less rigorous than it would be ideal, but it is the best possible approach given available data.⁴

We then move to the core of our study –the effect of exposure to homicides at the local level on birth weight:

$$BW_{jks} = \beta_0 + \beta_1 (Homicide_{jk1}) + \beta_2 (Municipality_j) + \beta_3 (Month_k) + \beta_4 (Trends_{jks}) + X_{jk}'\beta_5 + \varepsilon_{jk} \quad (2)$$

Where *BW* identifies birth weight of infants born in municipality *j*, month *k*, and state *s*, *X* is a vector of socio-demographic characteristics of mothers, and all other terms are the same as in equation 1. These characteristics include the municipal distribution of mother's education (Less than lower secondary [less than 9 years of schooling], Lower secondary graduate [9 years], Upper secondary or more [10 years or more]), marital status and health insurance, as previously described, and rural residence (50% or more of municipality households living in towns of less than 2,500 residents=1). The only departure from equation (1) is that now *l* identifies four distinct periods of exposure: Two trimesters preceding conception (*t*=1), first trimester of gestation (*t*=2), second trimester of gestation (*t*=3), third trimester of gestation (*t*=4). We use information on gestational age from the birth certificate to calculate periods of exposure. While birthweight is an accurate measure, gestational age is known to be measured imprecisely (Reichman and Hade 2001; Roohan, Josberger, Acar, Dabir, Feder, and Gagliano 2003). However, because gestational age is a dependent variable, its measurement error does not bias our estimates. Nevertheless, we tested the robustness of our findings by assuming that all births occur at term and "counting back" 39 weeks from birth date instead of using the provided measure of weeks of gestation. Results remain virtually unchanged. We use robust standard errors clustered at the municipality level. Descriptive statistics for all variables are presented in Table 1.

In order to test the hypothesis that the effect of exposure to local homicides varies over the course of the pregnancy we define the predictor of interest as the homicide rate in the municipality of mother's residence during each *trimester* of gestation. By including the homicide rate in the two trimesters that precede the conception, we capture a potential effect of local violence on fertility decisions driven by exposure to violence. To the extent that exposure to homicides in the months preceding (potential) conception alters fertility, the parameter estimates associated with homicides pre-conception and during gestation will capture different effects on birth weight. Homicides pre-conception captures the effect of selection, while homicides during gestation captures the effect of exposure to violence.

We then assess the potential role that prenatal care use plays in driving the effect of exposure to homicides on birth weight. We use the formulation presented in equation 2, but model prenatal care utilization as the outcome of interest. As a final step, we examine if the effect of homicide exposure on birth weight and behavioral changes varies across levels of

⁴Two-year averages are used in order to smooth out yearly fluctuations in the number of homicides in a municipality. The change in the homicide rate is used as a predictor instead of the homicide rate itself because the former should better capture the effect that the change in the level of violence has on fear of crime and the perceived risk of victimization. However, in alternative models not presented here we used the homicide rate at the beginning and the end of the five-year period. The results were consistent with those presented in Table 2B.

socioeconomic advantage of the mother by stratifying our models by the aforementioned socioeconomic status indicators.

4. Findings

Exposure to local homicides: Fertility and migration responses

Table 2 presents the results of the regression models for fertility. All models control for the state and municipal variables discussed above, but to conserve space, we present only the coefficients for the homicide rate. The results indicate that an increase in the homicide rate in the two trimesters that precede the (potential) conception has a positive effect on the birth rate at the municipality level, but the coefficient fails to reach significance (Model 1). There is no indication that, on average, women postpone or cancel fertility when facing increased violence. Lack of an overall effect may, however, obscure differential impacts across socioeconomic status. Models 2–4 in Table 2A examine changes in the socioeconomic composition of women giving birth at the municipal level as a result of homicide exposure. Very minor compositional changes are detected. The change in mother's education and health insurance is insignificant, and the increase in the proportion of mothers who are married is only significant at the $p < .10$ level. In sum, the evidence suggests no overall fertility responses and minimal selectivity of women giving birth in the face of rising local homicides.

Table 2B presents the results of the regression models examining the effect of violence on out-migration from Mexican municipalities using data from the 2010 census. The results suggest that the increase in the homicide rate has a minimal and statistically insignificant effect on the out-migration rate of women of childbearing age. Separate models by women's SES show insignificant effects except for women with middle education (9 years of schooling), with a very modest effect. Overall, these results suggest that the out-migration of women of childbearing age in response to higher homicide rates is unlikely to systematically alter the population at risk of live birth.

Exposure to local homicides and birth weight

We now move to the main analysis, the effect of maternal exposure to local homicides on birth weight and the probability of low birth weight (below 2,500 grams). Three models are presented for each outcome (Table 3). Model 1 includes only homicide rates for each trimester of gestation. This model captures the effect of exposure only. Model 2 adds the local homicide rate in the two trimesters preceding conception. This model accounts for (among other factors) potential selectivity of the exposed births due to pre-conception violence which, according to Table 2, should be negligible⁵. Model 3 adds demographic and socioeconomic controls at the municipality level. All models include controls for state-level economic trends and municipality and month fixed effects (not shown).

The analysis of birth weight indicates that an increase in the local homicide rate of 1 homicide per thousand residents results in an increase in birth weight of about 41 grams

⁵Tests for collinearity between variables capturing exposure in different trimesters of gestation indicate that multicollinearity does not pose a problem.

when exposure occurs in the first trimester of gestation. This is an unexpected finding. To the extent that exposure to violence induces acute maternal stress, a negative effect was predicted. This effect is concentrated in the first trimester, with no effect of exposure to homicides on birth weight later in the pregnancy. Exposure to homicides prior to conception does not affect birth weight (model 2). After we account for mothers' socioeconomic characteristics at the municipality level in model 3, an increase of 1 per 1,000 residents during the first trimester of gestation results in an average increase in birthweight of 37 grams. This is a very large influence if we consider that it is an intent-to-treat (ITT) effect measured among *all* women in the municipality, not only those that are affected by the homicides. If it was possible to estimate a treatment-on-the-treated effect (TOT) –the effect only on women who were actually affected by the homicides—this effect would be, necessarily, larger. The usual manipulation to obtain a TOT is to scale our estimates up by the fraction of the population affected by the treatment. Consequently, if 80% of women had been affected by local violence, the effect would be 25% larger, reaching 46 grams (37/.8); if 20% of women were affected, the effect would reach 185 grams.

Studies using an intent-to-treat estimator usually find small effects. For example, Hoynes et al. (2011) found an ITT of the Supplemental Nutrition Program for Women, Infants, and Children (WIC) on birthweight of 2.5 grams, while Almond et al. (2011) found an ITT of the Food Stamp Program on birthweight of 2.5 grams for whites and 4 grams for blacks. Using these major policy interventions as a benchmark, the effect we find in Mexico is extremely large. But this is related to the metric of the independent variable – the change in the municipal homicide rate of 1 per 1,000 residents. Only 3.3% of municipalities experienced such large change from one trimester to the next during the period under consideration. If we divide the coefficient by 10 in order for to capture a change in the homicide rate of 0.1 per 1,000 residents –a change experienced by as many as 17% of Mexican municipalities over the period considered— the effect would be 3.7 grams (37/100), which is closely comparable with that of the major policy interventions such as WIC or Food Stamps. Based on this benchmarking exercise, we conclude that the effect of local crime is substantial.

We also examine whether homicide exposure alters the proportion of low-weight births. An increase in local homicide in the first trimester of gestation results in an increase in the probability of low birth weight (<2,500 grams) of 1 percentage point (from a baseline of 8.3% average proportion of low birthweight in Mexico) but this effect fails to reach significance. The literature warns that exclusive focus on the 2,500 grams threshold may be unwarranted because some births classified as non-low birthweight may still be compromised in terms of mortality, morbidity and development (Abel, Wicks, Susser, Dalman, Pedersen, Mortensen, and Webb 2010; Barker 1998; Gage 2002; Morenoff 2003). We therefore use a 3,000 grams threshold and find a significant positive effect of exposure to local violence in the first trimester of gestation. As shown in the last column of table 3, an increase in 1 homicide per 1,000 population results in a decline in the proportion of births below 3,000 grams of 4.4 percentage points (or .44 percentage points if 0.1 homicides per 1,000 residents is used as metric)⁶.

Two distinct proximate factors induce variation in birth weight –gestational age and fetal growth given a particular gestational age. Discerning their relative importance matters because these factors have different etiology and consequences for later health and developmental outcomes (Kramer 1987). Table 4 evaluates the effect of homicide exposure on each one of these determinants of birthweight. Fetal growth is measured as gestational-week specific weight percentile (we use separate birthweight distributions by sex), and gestational age is measured as weeks of gestation. We find that the observed effect of violence exposure is entirely due to fetal growth, with no alteration of gestational age. Given that health-enhancing behavioral changes are more likely to affect fetal growth (Chomitz, Cheung, and Lieberman 1995), while the physio-endocrine stress reaction is more likely to affect gestational age (Dunkel-Schetter 2011), this finding indicates that the positive effect found could be driven by behavioral changes among pregnant women.

Exposure to local homicides and prenatal care utilization

We now explore behavioral responses to violence that could mediate the surprising positive effect on birthweight. We focus on prenatal care utilization given its importance for birth outcomes, and the fact that we have reliable information for all births. Prenatal care utilization is operationalized using three formulations: Whether women used prenatal care at all during the pregnancy; whether prenatal care started before the third trimester of gestation, and the number of prenatal care visits during pregnancy, with the following categories: No visits, 1–2, 3–4, 5, 6, 7, 8, 9, 10–12, 13 or more visits.

The results presented in Figure 2 show that an increase in the local homicide rate in the first trimester of gestation increases the use of prenatal care. Even if only 3% of Mexican women do not use prenatal care at all, this group is relevant because it includes the most disadvantaged women. The effect is a substantial 1.6 percentage-point increase associated with an increase of 1 per 1,000 in the homicide rate i.e. an average increase in prenatal care utilization from 97% to 98.6 %. This suggests that in face of a stressful environment, women use the strategies under their control to protect their pregnancies from potential harm, an effect likely stronger among disadvantaged women. Exposure to homicides in the first trimester also significantly increases the chances of obtaining prenatal care before the third trimester of the pregnancy; and augments the number of prenatal care visits, but this last effect fails to reach significance. Figure 2 also displays the variation in prenatal care utilization across women's level of socioeconomic advantage. We combine women's education, marital status, and health insurance –markers of socioeconomic advantage in Mexican society—to define three levels. *Low-SES* women have less than complete lower secondary schooling, are unmarried, and lack health insurance. *Middle-SES* women are all those with a lower secondary degree; and *High-SES* women are those with more than a lower secondary degree, married, and with health insurance⁷. We also distinguish urban from rural mothers.

⁶In models not shown (available from the authors upon request) we find that the change in local homicide rate does not affect the probability of a macrosomic birth (>4,000 grams), suggesting that the effect of birthweight is not driven by changes in the upper-end of the distribution.

⁷This typology does not exhaustively classify all possible combinations of values of the three socioeconomic variables. Rather, it creates ideal-types of socioeconomic disadvantage. The online appendix offers models across categories of each variable separately, and shows that the effect is consistently larger for more disadvantaged mothers, across all three variables considered.

As shown in figure 2, the effect of mother's homicide exposure on use of prenatal care varies substantially across mother's SES. Strikingly, only disadvantaged women increase their use of prenatal care when exposed to homicides, while the effect on high-SES women is null or, in one case, negative. The case of prenatal care visits is conspicuous. When exposed to a local homicide in the first trimester of the pregnancy, disadvantaged women increase the number of visits while advantaged women reduce their prenatal care visits (the latter effect is plausibly driven by excessive anxiety and fear among the most advantaged women—who are plausibly less accustomed to dealing with a hostile environment than disadvantaged women). It is actually this variation across SES that explains the null overall effect. Furthermore, only women living in urban areas react to homicides by increasing prenatal care visits, with no effect in rural municipalities. Given these findings, the women most likely to alter their use of prenatal care as a result of local homicides should be disadvantaged women living in urban areas. The last set of estimates in figure 2 confirms this hypothesis: The positive effect of homicide exposure is very large and significant for all measures of prenatal care among this group.

While the socioeconomic variation in use of prenatal care might be an artifact of the fact that virtually all advantaged women already receive prenatal care, providing little room for increased uptake as a result to exposure to violence, this is not the case for prenatal care visits or initiation of care before the third trimester. We find a consistent pattern across measures of prenatal care: In all cases, it is disadvantaged women living in urban areas who most strongly react to local violence by increasing prenatal care.

Socioeconomic heterogeneity in the effect of local homicides on birth weight

Our findings about the use of prenatal care provide a plausible mechanism for the positive effect of local homicides on birth outcomes: When exposed to violence in their immediate environment, women perceive risk and attempt to reduce harm on their pregnancies by engaging in the health-enhancing behaviors that they can control, in particular, the use of prenatal care. Given that disadvantaged and urban women are the most likely to increase their use of prenatal care, if prenatal care utilization does mediate the positive effect of homicide exposure on birth outcomes, we should observe that homicide exposure has the strongest influence on birthweight among socioeconomically disadvantaged urban women as well.

Figure 3 examines this hypothesis. It presents the results of models for the effect of first-trimester exposure to homicides on birthweight and low birthweight across levels of maternal SES and urban/rural residence. As predicted, the positive effect of early pregnancy exposure to homicides on birthweight is much larger among disadvantaged women. The effect of an increase in the local homicide rate in the first trimester of gestation on birth weight reaches 75 grams among disadvantaged women, while it is only 12 grams and statistically insignificant among the most advantaged mothers. Furthermore, the influence of an increase in the homicide rate on birthweight is much more pronounced among women in urban settings (77 grams) and insignificant among rural women, the same pattern found for prenatal care utilization. The effect on low birthweight goes in the expected direction but fails to reach significance among women of all levels of advantage. However, it is

significant among urban women. When, as in the case of prenatal care, we select the group of disadvantaged women living in urban areas, the positive effect of violence exposure on mean birthweight and the probability of low birthweight become statistically significant and substantial. For this group of women, the increase in local violence in the first trimester of gestation results in an average increase in birthweight of 135 grams, and a decline in low birth weight by 4.5 percentage points.

We cannot test the mediating role of prenatal care utilization by simply adding this potential mediator to the regression model because controlling for a post-treatment factor leads to a misleading assessment of the causal effect of homicide exposure as measured by the potential outcomes (Gelman and Hill 2007: 188–190). However, the large effect of local homicide exposure on prenatal care utilization is consistent with the hypothesis that less advantaged women, when exposed to local violence, engage in health-protecting behaviors, and this behavioral change mediates the positive effect of local homicide exposure on birth outcomes. As suggested by the literature on risk perception, it is plausible that more disadvantaged women experience and/or perceive enhanced vulnerability emerging from residential or social proximity to the location of the homicides (Hale 1996; Lagrange, Ferraro, and Supancic 1992; Pantazis 2000). At the same time, in order to act upon the sense of growing vulnerability and change their behaviors, women need a minimum of access to resources that make behavioral changes possible. In particular, we interpret a much larger positive effect in urban areas as determined by availability of prenatal care services in these locations⁸.

Further evaluation of the effect of local violence and the mechanism of influence

Our analysis is based on several assumptions that we now test in detail. An important assumption is that the birth outcomes of women living in municipality j are affected by homicides in her municipality, but not by homicides in contiguous municipalities. This assumption may be erroneous. Municipal boundaries are somewhat arbitrary and may be porous, such that homicides in neighboring municipalities may have substantial effects on birth outcomes (Morenoff 2003). In order to account for the effect of homicides in nearby municipalities, we include a spatially-lagged homicide rate as a predictor of birth weight and low birth weight. This spatially-lagged measure is computed using the full spatial contiguity matrix of Mexican municipalities (with queen criterion), and may be interpreted as the homicide rate in all surrounding municipalities per thousand residents. Model 1 in Table 5 presents the results of the models for birth weight and low birth weight respectively, including the spatially-lagged homicide rate for each trimester of gestation and the two trimesters preceding conception. Findings about effects of homicide exposure change minimally after homicides in neighboring municipalities are accounted for. This suggests that spatial correlation is not a source of bias.

⁸An alternative interpretation is that change is not driven by demand factors (women's uptake of prenatal care) but rather by supply factors (changes in healthcare provision). In alternative formulations we include controls for the time-varying number of hospital admissions at the state level as a proxy for changes in supply. Findings remain unaltered, suggesting that supply-side factors play a limited role, a tentative conclusion given the weakness of our proxy for supply-side changes.

We have formulated the treatment as the homicide rate at the municipal level under the assumption that the effect of each homicide will depend on the population size. This assumption might not be true. We conduct several robustness tests using alternative formulations of the treatment. First, we use the actual count of homicides in the municipality rather than the homicide rate. In the unlikely event that the impact is insensitive to population size, this would be the preferred formulation. Second, the homicide rate is right-skewed, with very large values resulting from homicides in small municipalities. To address this issue, we take the cubic root of the homicide rate. Third, the observed effect of homicide exposure may be driven by a small number of municipalities with a very large number of homicides. To account for this possibility we drop from the analysis the municipalities in which the number of homicides during the entire pregnancy of any woman was greater than 1,000 (0.8% of the cases in the sample). Models 2–4 of Table 5 replicate the analysis of the effect of homicide exposure on birthweight under these alternative specifications. Using the homicide count rather than homicide rate produces a similar effect on birthweight –a significant positive impact of homicide exposure in the early pregnancy on birth weight. The much smaller magnitude of the effect is expected: It assumes that the effect of one homicide is the same, regardless of population size. The cubic root formulation used to correct skewness does not alter the influence of homicide exposure. Excluding the small number of plausibly atypical municipalities with a very large number of homicides during the period considered results in comparable effects.

Models 5, 6 and 7 in Table 5 further examine the mechanism driving the effect of local violence on birth outcomes. Our hypothesized mechanism –mother’s risk perception and behavioral responses to local crime—is likely stronger in the municipalities experiencing a sudden spike in homicides, rather than those in which the homicide rate changes gradually. In order to test this hypothesis, we select the municipalities in which there is a “spike” in the homicide rate – defined as a fivefold or larger increase in the homicide rate from one first trimester to the next (model 5)⁹. Findings provide some support for the hypothesized mechanism: An increase in the local homicide rate in the first trimester of gestation results in a 45-gram rise in birthweight (compared with 37 grams among all municipalities). In contrast, in the municipalities that did not experience such spike, the effect of first-trimester exposure is only 32 grams and fails to reach statistical significance at the $p < .05$ level (Model 6). Furthermore, to the extent that the effect of local homicides on infant health is driven by women’s increased awareness and concern about violence, it is reasonable to expect a stronger effect in more densely populated municipalities, insofar as closer spatial proximity and more frequent interactions among residents should increase exposure and help spread the information about violent crimes. We use information on municipalities’ areas to create a measure of municipal population density, and evaluate the effect of an increase in the homicide rate in the top tertile of municipalities according to population density¹⁰. Findings show a stronger effect in denser municipalities, with violence exposure in the first trimester of gestation resulting in an increase of 98 grams in birthweight.

⁹A small amount was added to cells with a homicide rate of zero to perform this calculation (.001, .01, .05 produced identical results). Values were returned to zero to conduct the regression analysis.

¹⁰Municipal areas in square kilometers were computed using GIS shape files available from the Mexican National Institute for Statistics and Geography (INEGI).

Overall, these sensitivity tests suggest that the patterns of effects on birthweight are extremely robust, but confirm a weak effect on low birthweight. The findings are also consistent with maternal concern and anxiety as a potential mechanism linking increase in local violent crime to birth outcomes – as expressed by a stronger effect in municipalities that experienced a “violence spike” and in municipalities with higher population density.

Conclusions

Violence is unfortunately a common exposure, particularly among the more socioeconomically disadvantaged, and theory suggests its noxious effect can start even before birth. A persistent limitation for understanding the effect of prenatal exposure to a violent environment is unobserved heterogeneity: Violence is correlated with many other determinants of the outcomes of interest, such as economic deprivation, social disorganization, and discrimination, (Sampson 2011; Sampson, Raudenbush, and Earls 1997) and some of these determinants are difficult to measure and “control for”. The question about causal effects of maternal exposure to violence is further complicated by the diverse behavioral responses by pregnant women, which must be taken into account to provide a realistic assessment.

We have examined the causal effect of local homicides on birth outcomes, exploiting the increase in homicides during the second half of the 2000s in Mexico. This increase, we have argued, has likely been experienced as an exogenous shock by Mexican families. Our study includes not only the direct effect of homicide exposure but also (subject to data constraints) the potential changes in fertility and migration that determine whether exposure exists at all and the health-altering behaviors in which women may engage once they become pregnant, especially the use of prenatal care. We find that exposure to a local homicide early in the pregnancy results in an increase in birth weight. This increase is substantial if we consider that our estimate is an intent-to-treat effect, and is entirely driven by enhanced fetal growth, rather than by lengthening of gestational age. Our finding is surprising. It contradicts the well-documented hypothesis of a negative effect of maternal stress on birth outcomes, as driven by physio-endocrine stress and anxiety response. Furthermore, the finding is unlikely to emerge from positive selectivity of live births resulting from the loss of the weakest gestations, because homicide exposure does not significantly affect fertility or migration rates. What can account for it? We cannot absolutely rule out unobserved selectivity of women who conceive or who stay in the municipality as local violence increases. However, in order to drive the results and be consistent with the empirical findings, unobserved selectivity should *not* result in overall changes in fertility or migration, should *not* be correlated with socioeconomic characteristics of mothers included in the models, and should be *net* of municipality fixed effects, month fixed effects, and economic trends. These conditions are extremely unlikely.

Our analysis suggests an alternative mechanism. When exposed to growing local violence early in the pregnancy, women experience anxiety, and this anxiety prompts them to undertake health-enhancing behaviors under their control to protect the wellbeing of their pregnancies. Specifically, women increase their use of prenatal care. This response, we found, varies sharply by women’s socioeconomic advantage. It is the most disadvantaged

women living in urban areas who alter their behavior in the face of local violence. The heterogeneity of this response allows us to examine whether this behavioral mechanism may plausibly account for better birth outcomes resulting from exposure to a local homicide. If this behavioral response does indeed affect observed birth outcomes, the increase in birth weight should be more pronounced among disadvantaged women living in urban areas as well. This is exactly what we find. Birth outcomes improve the most among disadvantaged urban women, while no effect at all is detected among advantaged women. We interpret this finding as suggesting that low-resource women feel particularly vulnerable to violence, but in order to act upon this increased vulnerability they need access to the healthcare system, which is more likely to exist in urban areas.

Our findings do not imply that homicides are not a serious problem. A close parallel with the literature on the business cycle can be drawn. A consistent finding from that literature is that “recessions are good for your health” (Ásgeirsdóttir, Corman, Noonan, and Reichman 2012; Ruhm 2000), but this does not mean that recessions are a desirable event. What this literature highlights is a plausible behavioral *mechanism* leading to these positive effects. In cases of recession, evidence suggests that positive lifestyle changes (healthier diet, decline in alcohol and cigarette consumption, more exercise) compensate for detrimental stress effects. By the same token, our analysis suggests that health-enhancing behaviors—such as prenatal care—may more than compensate for the detrimental effects of stress. A potential policy implication is the relevance of making healthcare available and accessible to all women from the outset of pregnancy. But we hasten to add a note of caution. We cannot, with the data at hand, claim that it is prenatal care and not other unobserved health-enhancing behaviors highly correlated with prenatal care, which drives the observed effect. Our evidence that the positive effect of homicide exposure is null in rural areas supports the relevance of access to health care, but only more research will provide conclusive evidence about the mediating role of access to care in the association between local violence and birth outcomes. Our work does highlight the need to extend the study of causal effects from exposures per se to the role of population responses, and to consider the socioeconomic heterogeneity of such responses. We trust that more research will explore the role of individual agency—in the form of diverse adaptive responses—as a central mechanism linking environmental exposures and population health.

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Figure 1.
Homicide rate in Mexico (per 100,000) 1990–2010.

Figure 2.

Effect of change in homicide rate (homicides per 1,000 population) in the first trimester of gestation on prenatal care utilization, initiation of care before 3rd trimester, and number of prenatal care visits, across SES characteristics of women Mexico 2008–2010¹.

¹Shaded dots are parameter estimates, vertical bars are 95%-level confidence intervals.

Parameter estimates obtained from models predicting each measure of prenatal care utilization on homicide rates in each trimester of gestation and two trimesters preceding gestation. Models also include municipality and month fixed effects, controls for demographic and socioeconomic characteristics at the municipal level (infants' sex, mothers' age and age squared, education, marital status, parity and health insurance), as well as state-level trends in unemployment, average wage, and female labor force participation.

Figure 3.

Effect of change in homicide rate (homicides per 1,000 population) in the first trimester of gestation on birth weight and low birthweight, across level of socioeconomic advantage of women Mexico 2008–2010¹.

¹Shaded dots are parameter estimates, vertical bars are 95%-level confidence intervals.

Parameter estimates obtained from models predicting birth weight and low birthweight on homicide rates in each trimester of gestation and two trimesters preceding gestation. Models also include municipality and month fixed effects, controls for demographic and socioeconomic characteristics at the municipal level (infants' sex, mothers' age and age squared, education, marital status, parity and health insurance), as well as state-level trends in unemployment, average wage, and female labor force participation.

Table 1

Descriptive statistics.

Variable	Mean/Pct.	Std. Dev.	Min	Max
Birth weight	3155.7	505.7	500	6500
% low birth weight (<2,500 grams)	0.085	0.27	0	1
% births <3,000 grams	0.320	0.20	0	1
Weeks gestation	38.87	1.68	22	42
% utilized prenatal care	0.97	0.17	0	1
% started prenatal care before 3 rd trimester	0.89	0.22	0	1
# prenatal care visits (continuous)	7.02	3.23	0	30
Categorical: 0 visits	3.1%			
1–2 visits	3.7%			
3–4 visits	11.3%			
5 visits	11.0%			
6 visits	14.3%			
7 visits	13.1%			
8 visits	14.8%			
9 visits	12.4%			
10–12 visits	13.8%			
13 or more visits	2.5%			
Mother's age	25.76	6.23	11	46
Mother's age squared	702.6	342.0	121	2116
Rural residence	0.18	0.39	0	1
Mother's education				
LT lower secondary (0–8 years schooling)	33.54%			
Lower secondary grad. (9 years schooling)	30.60%			
Secondary or more (10+ years schooling)	35.86%			
Mother is married	0.49	0.50	0	1
Mother has health insurance	0.32	0.47	0	1
Parity				
First birth	36.50%			
2	28.86%			
3	18.94%			
4 or more	15.70%			
Homicide rate per 1,000 1 st trimester (annualized)	.151	.248	0	22.04
Homicide rate per 1,000 2 nd trimester (annualized)	.150	.274	0	41.95
Homicide rate per 1,000 3 rd trimester (annualized)	.159	.239	0	41.95
Female labor force participation	41.67%	4.22	28.72	55.47
Unemployment	4.57%	1.73	1.06	9.54
Hourly wage (Mexican pesos)	28.28	5.46	15.98	49.33
Number of individual observations	5,222,465			
Number of clusters (municipality*month)	81,350			

Table 2

Table 2A. Effect of changes in the municipal homicide rate on birth rate at the municipality level. Mexico 2008–10¹

	All women	Compositional change. Increase in proportion of women who are:		
		Low education ²	Married	Have health insurance
Homicide rate (two trimesters pre-conception)	15.698 (7.796)	−0.040 (0.033)	0.096 [†] (0.051)	−0.039 (0.118)
Constant	53.887*** (8.331)	0.351*** (0.045)	0.606*** (0.035)	0.393*** (0.119)
N (Municipality*Month)	81,350	81,350	81,350	81,350

Effect of change in the municipal homicide rate on proportion of childbearing-age women out-migrating from municipality of residence 2005–2010³.

All women	Heterogeneity of effect. Effect among women with following characteristics ⁴ :						
	Education			Marital Status		Health Insurance	
	Low	Middle	High	Married	Unmarried	Insured	Uninsured
Change homicide rate 2003/04–2008/09	0.004 (0.004)	0.014 ^{***} (0.005)	0.002 (0.007)	0.004 (0.002)	0.000 (0.003)	0.014 (0.010)	0.002 (0.004)
Constant	0.053 ^{***} (0.009)	0.070 ^{***} (0.012)	0.110 ^{***} (0.017)	0.024 ^{***} (0.005)	0.029 ^{***} (0.006)	0.089 ^{***}	0.046 ^{***}
	2417	2417	2412	2417	2417	2399	2417

¹ Homicide rate is number of homicides per 1,000 population, birth rate is number of births per 1,000 women ages 15–64. Models include municipality and month fixed effects, and controls for state-level trends (unemployment, average wage, and female labor force participation). Robust standard errors clustered at the municipality level used.

*** p<0.001,

** p<0.01,

* p<0.05,

[†] p<.10

Source: Merged 2008–2010 Birth Certificate dataset and Vital Statistics homicide dataset.

² Low education: Less than 9 years of schooling.

³ OLS models. Homicide rate is number of homicides per 1,000 population. Childbearing-age women are 15–44 years old in 2005.

⁴ Low education: Less than 9 years of schooling. Middle education: 9 years of schooling. High education: More than 9 years of schooling. Health insurance: Woman has any type of formal health insurance. Models include municipality and month fixed effects, and controls for state-level trends (unemployment, average wage, and female labor force participation), regional indicators (South, Center, West, Northwest, Northeast) and rural municipality indicator.

Source: 2000 and 2010 National Population Censuses, 2005 National Population Count.

Table 3

Effect of change in homicide rate (homicides per 1,000 population) prior and during pregnancy on birth weight and the probability of low birth weight. Mexico 2008–2010¹.

	Birth weight		Low birth weight (<2,500 gr.)			Weight<3,000	
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 3
Homicide rate 3 rd trim.	-17.525 (18.071)	-17.344 (18.205)	-19.157 (18.266)	0.003 (0.007)	0.003 (0.007)	0.003 (0.007)	0.012 (0.016)
Homicide rate 2 nd trim.	-7.345 (16.560)	-6.167 (17.007)	-7.970 (16.489)	-0.009 (0.007)	-0.009 (0.007)	-0.009 (0.007)	0.004 (0.016)
Homicide rate 1 st trim.	38.412* (17.194)	40.937* (17.124)	36.608* (17.174)	-0.011 (0.008)	-0.011 (0.009)	-0.010 (0.009)	-0.044*** (0.015)
Homicide rate precon.		-19.962 (26.462)	-24.174 (27.742)		0.003 (0.011)	0.004 (0.011)	-0.002 (0.020)
Mothers' age			24.712*** (2.191)			-0.010*** (0.001)	-0.019*** (0.002)
Mothers' age squared			-0.405*** (0.039)			0.000*** (0.000)	0.000*** (0.000)
Male birth			81.527*** (3.703)			-0.011*** (0.002)	-0.072*** (0.004)
Mothers' education			13.172*** (2.529)			-0.007*** (0.001)	-0.017*** (0.003)
Parity			29.804*** (2.222)			-0.007*** (0.001)	-0.023*** (0.002)
Married			29.014*** (4.198)			-0.008*** (0.002)	-0.027*** (0.004)
Health insurance			1.116 (5.182)			0.000 (0.002)	-0.005 (0.005)
Constant	3,262.462*** (35.402)	3,262.603*** (35.103)	2,753.061*** (45.107)	0.066*** (0.012)	0.066*** (0.012)	0.229*** (0.020)	0.707*** (0.056)
N	81,350	81,350	81,350	81,350	81,350	81,350	81,350

¹ All models include municipality and month fixed effects, and controls for state-level trends in unemployment, average wage, and female labor force participation.

*** p<0.001,

** p<0.01,

* p<0.05,

[†] p<.10

Effect of change in homicide rate (homicides per 1,000 population) prior and during pregnancy on fetal growth and gestational age, Mexico 2008–2010.

Table 4

	Fetal growth percentile			Weeks of gestation		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Homicide rate 3 rd trim.	-1.085 (1.195)	-1.085 (1.195)	-1.159 (1.213)	-0.036 (0.065)	-0.029 (0.065)	-0.028 (0.065)
Homicide rate 2 nd trim.	-0.477 (1.059)	-0.477 (1.059)	-0.685 (1.020)	0.032 (0.075)	0.037 (0.074)	0.039 (0.074)
Homicide rate 1 st trim.	2.920*** (1.013)	2.920*** (1.013)	2.712*** (1.010)	0.005 (0.077)	0.019 (0.074)	0.014 (0.074)
Homicide rate precon.	0.550 (1.950)	0.550 (1.950)	-0.092 (2.142)		-0.093 (0.098)	-0.075 (0.099)
Mothers' age			1.162*** (0.140)			0.038** (0.012)
Mothers' age squared			-0.017*** (0.002)			-0.001*** (0.000)
Male birth			-0.396* (0.230)			-0.019 (0.018)
Mothers' education			1.375*** (0.205)			-0.037 (0.030)
Parity			1.848*** (0.166)			0.018 (0.021)
Married			2.213*** (0.335)			-0.079 [†] (0.043)
Health insurance			1.200*** (0.329)			-0.110*** (0.022)
Constant	62.754*** (3.436)	62.754*** (3.436)	37.138*** (3.873)	38.841*** (0.134)	38.842*** (0.133)	38.555*** (0.181)
N	81,329	81,329	81,329	81,329	81,329	81,329

All models include municipality and month fixed effects, and controls for state-level trends in unemployment, average wage, and female labor force participation.

*** p<0.001,

** p<0.01,

* p<0.05,

[†] p<.10

Table 5

Effect of change in homicide rate (homicides per 1,000 population) prior and during pregnancy on birth weight. Alternative formulations of homicide exposure. Mexico 2008–2010.

	Birthweight						
	M1	M2	M3	M4	M5	M6	M7
	Contiguous Municip. ¹	Homicide count ²	Cubic root Homic. rate ³	Truncated sample ⁴	Homicide spike ⁵	No homicide spike ⁵	High density municip. ⁶
Hom. rate 3 rd trim.	-18.683 (18.469)	-0.032 (0.031)	-0.335 (0.514)	-19.226 (19.288)	-6.964 (18.781)	-20.305 18.469	98.076* (53.031)
Hom. rate 2 nd trim.	-9.954 (16.791)	0.012** (0.006)	0.103 (0.478)	-13.539 (16.691)	-1.338 (16.908)	-13.104 19.733	1.758 (30.025)
Hom. rate 1 st trim.	34.932* (17.370)	0.015* (0.006)	0.777† (0.458)	34.207† (19.217)	44.845* (17.529)	31.927† 18.483	98.128*** (26.363)
Hom. rate precon.	-26.704 (27.432)	-0.005 (0.010)	-0.250 (0.478)	-2.177 (26.538)	-7.289 (27.176)	-29.244 29.202	-61.696 (47.850)
Hom. Rate T3 cont.	-1.428 (3.028)						
Hom. Rate T2 cont.	3.902 (3.611)						
Hom. Rate T1 cont.	0.755 (3.143)						
Hom. Rate prec. cont.	0.462 (3.636)						
Mothers' age	24.757*** (2.192)	24.666*** (2.192)	24.677*** (2.193)	24.806*** (2.190)	25.012*** (2.425)	24.018*** (2.878)	26.582*** (4.113)
Mothers' age squared	-0.406*** (0.039)	-0.404*** (0.039)	-0.404*** (0.039)	-0.407*** (0.039)	-0.412*** (0.043)	-0.390*** (0.052)	-0.430*** (0.074)
Male birth	81.133*** (3.700)	81.488*** (3.702)	81.398*** (3.706)	81.736*** (3.701)	80.731*** (4.164)	81.397*** (4.890)	84.701*** (6.911)
Mothers' education	13.202*** (2.525)	13.261*** (2.523)	13.172*** (2.532)	13.079*** (2.531)	13.289*** (2.817)	12.908*** (3.253)	12.212*** (4.378)
Parity	29.915*** (2.221)	29.818*** (2.222)	29.739*** (2.224)	29.819*** (2.222)	29.466*** (2.491)	29.764*** (2.836)	22.682*** (4.310)
Married	28.982*** (4.196)	29.163*** (4.196)	28.968*** (4.191)	29.013*** (4.208)	29.753*** (4.697)	31.036*** (5.634)	20.115** (8.383)
Health insurance	1.897 (5.211)	1.116 (5.129)	1.135 (5.194)	2.284 (5.068)	-0.052 (5.185)	2.987*** (6.242)	14.084** (6.837)
Constant	2,755.2*** (45.148)	2,755.2*** (44.258)	2,753.9*** (45.593)	2,763.9*** (44.434)	2,735.3*** (51.075)	2754.705*** (52.799)	2,869.4*** (85.665)
N	81,278	81,350	81,350	81,142	29,111	52,031	28,152

All models include municipality and month fixed effects, and controls for state-level trends in unemployment, average wage, and female labor force participation.

p<0.001,

**
p<0.01,

*
p<0.05, p<.10

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¹ Model includes homicide rate in all contiguous municipalities using full spatial contiguity matrix of Mexican municipalities (with queen criterion),

² Predictor is count of homicides in municipality (homicides per 1,000 population).

³ Predictor is cubic root of homicide rate (homicides per 1000 population).

⁴ Truncated sample excludes municipalities in which the number of homicides during entire pregnancy of any woman > 1,000.

⁵ Sample restricted to municipalities that experienced a fivefold or larger increase in the homicide rate from one first trimester to the next.

⁶ Sample restricted to one-third of municipalities with highest population density.