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Abstract*

This paper uses microdata from Brazilian vital statistics natality and mortality data between 2000 and 2010 to estimate the impact of in-utero exposure to local violence—measured by homicide rates—on birth outcomes. Focusing on small communities, where it is more plausible that local homicide rates reflect actual exposure to violence, the analysis shows that exposure to violence during pregnancy leads to deterioration in birth outcomes: one extra homicide during the first trimester of pregnancy increases the probability of low birthweight by around 6 percent. Results are particularly pronounced among children of poorly educated mothers, implying that violence compounds the disadvantage that these children already suffer as a result of their households' lower socioeconomic status.

JEL classifications: I12, I14, J13, J88
Keywords: Birthweight, Cost of crime, Prenatal stress, Brazil

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1. Introduction

In this project we analyze birth outcomes of children whose mothers were exposed to high levels of violence in their local environment during pregnancy. There is considerable evidence showing that the nine months in utero are critical in shaping a person's life, affecting a variety of economic and non-economic outcomes even in adulthood. Although there is a small but growing literature in economics showing that maternal stress and exposure to extreme events (including conflict and terrorist attacks) during pregnancy affect birth outcomes, the impact of day-to-day violence is, by and large, understudied.

Exposure to violence in utero might affect birth outcomes directly through the mother's fear of victimization and psychological stress, which is in turn known to lead to worse birth outcomes. Violence can also affect mothers and hence the health of the fetus directly through victimization, with its ensuing negative economic, physical, and psychological consequences. Indirect effects, such as changes in labor supply, might also be at play, with effects on household income, increased difficulties in, or higher costs of, accessing local health services due to safety concerns, or even changes in fertility, possibly affecting observed birth outcomes through selection. Additionally, resource diversion on the part of both households and communities in order to prevent or counteract violence might lead to reductions in expenditures associated with children's well-being.

This analysis focuses on Brazil, a country with one of the highest levels of violence worldwide (UNODC, 2011), with a homicide rate of 21 deaths per 100,000 population (as of 2011), approximately five times the rate in the United States and almost 20 times the rate in the United Kingdom. Homicide is the leading cause of death in men aged 15-44 (Reichenheim et al., 2011), and day-to-day violence is a top concern among citizens of Brazil. In the 2010 Latinobarometer, about 16 percent of Brazilian respondents listed violence and public security as the most important problem (Latinobarometer, 2010), and existing estimates put the direct costs of violence and crime at between 3 and 5 percent of annual GDP (Couttolene, Cano, Piquet Carneiro, and Phebo, 2000; Kahn 1999; Heinemann and Verner, 2006; Velasco Rondon and Viegas, 2003; World Bank, 2006).[1]

[1] Methodologies such as contingent valuation surveys and willingness-to-pay methods (see Soares, 2010, for a description of the methods and a survey of the findings) have not been applied in the Brazilian context.

In order to assess the impact of violence on birth outcomes, we combine microdata on all births for 11 years (2000 to 2010) from official birth records with information on all homicides that occurred over the same period obtained from official death records. Vital statistics provide the date of birth and the place of residence of the mother up to the municipality level. Similarly, for homicides, the data provide information on the date and municipality of occurrence of the death. This allows us to identify the incidence of homicides during different stages of pregnancy in the mother's municipality of residence.

Homicide rates are often used as crime and violence indicators (UNODC, 2011). Evidence for Brazil, in particular, shows a close correlation between different forms of violent crime and homicides (World Bank, 2006).[2] Because of their severity, underreporting is not generally a concern (Heinemann and Verner, 2006), and homicides are more likely to be followed up by police investigations and media coverage relative to other types of crime, making them particularly visible to the public. As uniform crime reports are not publicly available for Brazil, homicide rates from death records constitute a unique source of information on violence that is uniform across space and time.

The rich information available in the vital statistics data allows us to measure the effects of violence on a variety of outcomes, including birthweight, APGAR scores, gestational length and infant mortality, as well as potential margins of selection due to fertility, abortion, and miscarriage.

Identification is based on a difference-in-differences strategy across geographical areas and time (conditional, in some specifications, on municipality linear trends). This allows us to obtain credible estimates of causal impact and provides the opportunity for a falsification test. The sheer amount of data helps us obtain precise estimates: this is crucial, as some of these phenomena (e.g., infant mortality) are rare events and their statistical—although not necessarily their economic—magnitude may be very small and hard to detect in sample surveys.

Most of the analysis focuses on small, primarily rural, municipalities (with populations of less than 5,000), for which municipality-level homicide rates provide a localized measure of violence.

[2] A significant proportion of murders in Brazil is associated with drug trafficking and the ensuing disputes over territory, distribution, and leadership (UNODC, 2005). Murders based on drug trafficking—but not exclusively those—are related to a wide variety of other violent activities, such as robberies, kidnapping, assaults, and muggings (Heinemann and Verner, 2006).

To preempt our results, we show that in small municipalities, one extra homicide during pregnancy leads to an increase in the probability of low birthweight (<2.5 kg.) of around half a percentage point, a 6 percent increase relative to baseline (8 percent). Consistent with findings elsewhere in the literature, the effect seems to be concentrated in the first trimester of pregnancy. The estimated effect is economically meaningful, being approximately 10 times the effect estimated for the United States of being a recipient of Food Stamps (Almond, Hoynes, and Whitmore Schanzenbach, 2011) (although clearly a much larger fraction of households are in receipt of Food Stamps compared to those exposed to homicides). The effect seems to be largely driven by increased prematurity rather than intrauterine growth retardation. We find no effect on child mortality or margins of endogenous fertility.

2. Birth Outcomes and In Utero Experiences: The Effect of Exposure to Violence

The consequences of low birthweight and fetal health more generally on long-run outcomes, such as educational attainment, later life health, mortality, and labor market performance have been established in a large body of literature (Alderman and Behrman, 2006; Almond, Chay, and Lee, 2005; Almond and Currie, 2011b; Currie, 2011; Currie and Moretti, 2007; Royer, 2009; Victora, Kirkwood, Ashworth, Black, Rogers, Sazawal, Campbell, and Gore; 1999). Low-birthweight infants display a substantially increased risk of neonatal or infant death and are more likely to require additional outpatient care and hospitalization during childhood, adding to the private and social costs of poor birth outcomes. Of those living into adulthood, some may suffer from cognitive and neurological impairment, conditions typically associated with lower productivity in a range of educational, economic, and other activities, as well as from increased morbidity (e.g., risk of cardiovascular disease, diabetes, and hypertension).

The importance of fetal shocks and of the circumstances in utero on birth and later life outcomes has only been recently acknowledged by economists, leading to resurgent interest both in the theoretical and in the empirical literature. There are now numerous empirical studies showing that, consistent with Barker's fetal origin hypothesis, the nine months in utero constitute a critical period of a person's life, shaping subsequent health, educational, and labor market outcomes (Almond and Currie, 2011a; Almond and Currie, 2011b; Currie, 2011).

Almond and Currie (2011a) categorize factors affecting the prenatal environment into three groups: those affecting maternal and thereby fetal health (such as nutrition and infection), economic shocks, and environmental pollution. A number of studies, in particular, have established a link between household maternal nutrition and birth outcomes, especially birthweight, one of the most important and easiest to measure predictors of economic and non-economic outcomes in adulthood. Some studies focus on the role of redistributive policies (see, for example, Almond, Hoynes, and Whitmore Schanzenbach, 2011 on the U.S. Food Stamps program and Amarante, Manacorda, Miguel, and Vigorito, 2011 on the Uruguayan PANES), while others focus on the role of famines, natural disasters, or even fasting during pregnancy (Almond, 2006; Almond and Mazumder, 2011; Banerjee, Duflo, Postel-Vinay, and Watts, 2010). For Brazil, Rocha and Soares (2012) show that negative weather shocks during pregnancies lead to a significant reduction in gestational length and birthweight. Other studies focus instead on the disease environment during pregnancy (see Almond, 2006 and Kelly, 2011 on maternal influenza and Barreca, 2010 for maternal exposure to malaria) and on pollution (Currie and Walker, 2011; Chay and Greenstone, 2003 on air pollution, Almond, Edlund and Palme, 2009 on nuclear fallout, and Reyes, 2007 and Nilsson, 2011 on leaded gasoline), showing that both play substantial roles in affecting birth and later outcomes.

Despite evidence that maternal stress during pregnancy negatively affects cognition, health, and educational attainment of children through elevated levels of the stress hormone cortisol (Aizer, Stroud, and Buka; 2009), presumably because of data limitations, the effect of exposure to crime and violence on birth outcomes has received considerably less attention.

A stream of literature focuses on terrorist attacks and conflict. Camacho (2008) finds that landmine explosions during the first trimester of pregnancy have a significant negative effect on birthweight in Colombia, with one extra landmine explosion during pregnancy leading to a decrease in birthweight by 8.7 grams. Ecclestone (2012) shows that exposure to the 9/11 terror attacks among pregnant women in New York City led to a reduction in birthweight of between 12 and 14 grams and an elevated level of prematurity. In a setting closer to ours, Mansour and Rees (2012) find a modest but imprecisely estimated increase in the fraction of low birthweight infants in response to an increase in noncombatant fatalities in the West Bank and Gaza during the second Intifada.[3]

Although clearly related to our paper, these studies focus on the effect of rare, extreme events, implying that their findings may not necessarily be applicable in other settings where violence is endemic.

3. Background, Trends, and Data

3.1 Births and Birth Outcomes

In order to characterize the distribution of birthweight and other birth outcomes, in the rest of the paper we use microdata from birth certificates, which are collected by the Brazilian Ministry of Health through *DATASUS*, literally the *Departamento de Informática do Sistema Único de Saúde* (SUS).[4] The data provide a large array of information on pregnancy and newborns' outcomes as well as on mothers' characteristics. Coverage is practically universal: data from the 2010 population census show that more than 99 percent of children born between 2000 and 2010 indeed have birth certificates.

Summary statistics for the period 2000-2010 are reported in the top panel of Table 1. The data provide information on more than 30 million births over the period. As noted, the primary units of observation in the analysis are municipalities, relatively small geographical units roughly equivalent to a U.S. county. In the table we have information on 5,508 municipalities.[5] At a total population of just over 181 million, each of these municipalities accounts on average for 33,000 individuals. Obviously, however, population size varies tremendously across municipalities: while São Paulo and Rio de Janeiro account for more than 11 and 6 million inhabitants respectively, more than 20 percent of municipalities have fewer than 5,000 inhabitants. For this reason, in the table we present results for all of Brazil (column (1)) and separately for the different classes of municipalities based on population size. For this we use the standard classification from the National Statistical Office (IBGE) (population 1 to 5,000; 5,001 to

[3] There is very little evidence on the effect of mother's victimization. One exception is Aizer (2011), which shows that mother's domestic-violence-induced hospitalization considerably reduces birthweight.
[4] The information on births is first collected by the health institution where the birth took place and then forwarded to the state's health secretariat (via means of the municipal health secretariat), which in turn is responsible for entering the information into the central database (FUNASA, 2001). In the rare case of a home birth, this information is submitted by medical staff attending the birth.
[5] We have excluded the few municipalities that split into newer municipalities between 2000 and 2010.

20,000; 20,001 to 100,000; 100,001 to 500,000 and 500,001 or more). Smaller municipalities account for around 2 percent of all births.

The table illustrates that, with an incidence of low birthweight (less than 2.5 kg.) of around 8 percent, Brazil ranges above the average for OECD countries but considerably below the highest rates in some low-income countries (UNICEF, 2006). Around respectively one and half a percent of children are born with very low (<1.5 kg.) and extremely low (<1 kg.) birthweight. The data also provide information on APGAR scores, gestational length, gender, race, and a number of mother characteristics. Roughly speaking, birth outcomes are worse the greater the municipality size, although children in very large municipalities (>500,000) seem to perform better than children in large municipalities (100,000 to 500,000) among a number of dimensions.

Figure 1, left-hand side panel, reports average (across the entire period) low-birthweight rates in all Brazilian municipalities: darker areas correspond to municipalities with greater incidence of low birthweight. The municipalities with the highest rates of low birthweight are clustered mainly in a number of states, Maranhão and Amapá, in the Northeast and North, respectively, as well in the Southeastern states of Minas Gerais and São Paulo and Rio Grande do Sul in the South.

3.2 Infant Mortality

The middle panel of the table reports data on infant mortality. Data come from death certificates, which are also collected by *DATASUS*, and record very detailed causes of death, including non-natural deaths classified as homicides that we use below, as well as the date and municipality of occurrence of the death. The data also provide information on infant mortality. Infant mortality data refer to children born alive for which a birth certificate has been produced, and hence exclude fetal deaths.

The data allow us to estimate four rates: early neonatal mortality (within seven days since birth), neonatal mortality (within 28 days since birth), perinatal mortality (within the first 22 weeks since birth) and infant mortality (within the first year since birth). At nine deaths per 1,000 children, early neonatal mortality accounts for the bulk of deaths within the first year of life. Infant mortality is on average 14 per 1,000 children. Again, there is a clear gradient across municipalities, with larger municipality size being associated with worse outcomes, and with very large municipalities being somewhat below trend.

3.3 Homicides

The third panel of Table 1 reports data on homicides. These and all other aggregate statistics in the rest of the table that vary only by municipality and time are weighted by the number of births, meaning that municipality X times mean receives a weight proportional to the number of births in that cell.

For the period 2000-2010, more than 528,000 homicides are recorded, equivalent to a *yearly* homicide rate of around 26 per 100,000 individuals. Again, homicide rates tend to be higher the larger the municipality. Still, even in small municipalities, the homicide rate is 9 per 100,000 individuals. The data also provide location of death. This can be in a health institution, in one's home, in the street, or elsewhere. Clearly, when the death occurred in a health institution, the homicide might have been committed elsewhere, possibly even in another municipality, inducing considerable error in the measure of local violence that we use. The subsequent rows of the table show that around 40 percent of deaths resulting from homicides happen on the street and around 50 percent either on the street or in one's residence. Interestingly, the latter is only 44 percent in very large municipalities, where hospitals are typically located. This suggests that a fraction of homicides for which the death occurs in hospitals are likely to be committed in other municipalities. Because of this, in most of the analysis we focus on homicides for which the death occurred *on the street*. These are also likely to be the most visible and hence stress-inducing homicides, which might possibly affect pregnancy outcomes.

The middle panel of Figure 1 reports the distribution of homicide rates (in the street) across Brazilian municipalities. Municipalities with higher incidence of homicides are in the more densely populated and more urbanized areas along the coastline, as well as in the state of Bahia in the Northeast of Brazil. Municipalities with high rates of homicides are also to be found in the less densely populated states of Mato Grosso and Pará, covering some of the Amazon region.

Although this is not immediately evident in Figure 1, once differences in population size across municipalities are taken into account, a clear positive correlation between local homicide rates and low birthweight emerges. This is shown in Figure 2, left hand-side panel, which plots the cross-sectional relationship between the fraction of low-weight births and the annual homicide rate (in the street) across all Brazilian municipalities. A predicted regression line is also superimposed and larger circles correspond to larger cities. The data clearly show that, across municipalities, higher homicide rates are associated with worse birth outcomes: the estimated coefficient is 1.6 per thousand births and highly significant at conventional levels, implying that one extra homicide out of 100,000 people is associated with 1.6 extra low-weight births out of 1,000 births. It is also clear that larger municipalities tend to outperform smaller municipalities along both of these dimensions. One possible interpretation of these correlations is that higher homicides rates are responsible for worse birth outcomes. This conclusion may be unwarranted, as different municipalities vary in characteristics which are potentially associated with both birth outcomes and mortality rates.

Indeed, the bottom part of Table 1 shows that municipalities of different sizes vary along a number of dimensions, such as income, literacy rate, and rates of urbanization. These data (like most of the municipality-level data that we use in the regressions) come from decennial population censuses.[6] There is evidence that larger municipalities outperform smaller ones in many socioeconomic dimensions, such as literacy rate and per capita income.

Differences in socioeconomic status and living standards across areas are also evident in the right-hand side panel of Figure 1, which displays average household income by municipality, with higher income being represented by darker areas. The Southeastern states of São Paulo, Rio de Janeiro, and parts of Minas Gerais are those with the highest average household income.

4. Econometric Methodology

As already emphasized, the difficulty in estimating the causal effect of violence on birth outcomes is that characteristics of different residential areas are unobservable to the econometrician. Some of these unobservable characteristics might be correlated with both newborns' health outcomes and homicide rates, even in the absence of a causal effect of violence on birth outcomes. For example, children born in poorer areas are more likely to display negative

[6] The majority of the data come from population census micro-data. Additional variables have been obtained from *DATASUS.* (http://www2.datasus.gov.br/DATASUS/index.php?area=0206andVObj=http://tabnet.datasus.gov.br/cgi/deftohtm.exe?ibge/censo/cnv/crianpobr). Data are available for 2000 and 2010 and we have then interpolated linearly across these two dates to estimate their value in every intervening month.

birth outcomes due to the lower socioeconomic characteristics of their parents or worse provision of health services in their neighborhood, and, possibly, to be exposed to a higher (or lower) degree of violence. In this case, one would erroneously conclude that higher homicide rates lead to worse (or better) birth outcomes, a classic case of failed inference based on observational data.

In order to circumvent this problem, we propose to use a simple difference-in-differences identification strategy that relies on differential changes in homicide rates across municipality and time: this provides a way to control for unobserved time-invariant municipality characteristics and to subsume aggregate time effects.

In formulas we estimate the following model:

$$Y_{mt}=\beta_0+\beta_1\, HOM_{mt}+ X_{mt}\,\beta_3+ d_m +d_t +u_{mt} \qquad (1)$$

where Y_{mt} is the average outcome variable (birthweight, still birth, infant mortality, APGAR scores, gestational length, etc.) in municipality m at time t, HOM_{mt} is the local homicide rate, X_{mt} are vectors of average (across all individuals in each cell) individual characteristics as well as time-varying municipality-level characteristics, d_m and d_t are respectively municipality and time-fixed effects, and u is an error term. We estimate equation (1) on aggregate month X municipality-level data, which is the level of variation of the homicide data (rather than on individual data), for computational purposes. All regressions are estimated using WLS, with weights given by the number of births in each cell.

In the empirical analysis, we estimate the effect of the homicide rate at different stages of pregnancy (i.e., first, second, and third trimester) and test for the validity of the identification assumption by introducing in the regressions additional pre- and post-pregnancy homicide rates as additional regressors. One would expect homicide rates pre- and post-pregnancy not to affect birth outcomes: finding a significant coefficient on the latter would point to a violation of the identification assumption.

In the following, we measure trimesters of pregnancy starting from the date of conception. We recover the latter based on the child's date of birth minus the length of gestation. As the length of gestation is recorded in intervals in our data (<22, 23-27, 28-31, 32-36, 37-41, >41 weeks), we use the mid-point of each interval. This approach has multiple advantages. First, it allows us to correctly measure exposure in different trimesters of pregnancy, which would not be possible if we counted retrospectively since the time of birth (as typically done in this literature) and ignored the variation in the length of gestation across pregnancies. Second, it allows us to directly estimate the effect of homicides on the length of gestation, a potentially interesting outcome in itself. Third, and related to the latter, it allows us to obtain estimates of the impact of homicides on other outcomes (e.g., birthweight) that are correlated with length of gestation and that are free of potential selection bias.

5. Empirical Results

5.1 Birthweight

Table 2 presents estimates of equation (1) for small municipalities (<5,000 individuals). Small municipalities are concentrated in a few states (Tocantins, Piauí, Goiás, Minas Gerais, São Paulo, and Rio Grande do Sul) and geographically rather dispersed (see Figure 4). The table reports results on average birthweight (in grams) and on the fraction of low, very low, and extremely low-weight births (per 1,000 births). Column (1) of Table 2 reports a simple difference-in-differences estimate for the effect of the homicide rate on average birthweight in the first, second, and third trimesters since conception. Regressions include only municipality and month of conception fixed effects. Homicide rates here are computed at the quarterly level (i.e., number of homicides per quarter over total population). The data show a negative and very precisely estimated effect of the homicide rate in the first trimester of gestation on birthweight. The estimated effect of an increase by one in the number of quarterly homicides per 100,000 individuals in column (1) is just below half a gram (-0.43 grams.) This implies that in an average municipality in this class (around 3,700 individuals), one extra homicide will lead to a reduction in average birthweight among children exposed to that homicide in their first trimester of pregnancy of around 12 grams (=(0.43 X 100,000) /3,700). This is a small effect, on the order of 0.4 percent relative to an average birthweight of 3.210 kg. For comparison, for Colombia, Camacho (2008) finds that one landmine explosion during early pregnancy reduces birthweight by 7.5 grams.

The estimates for the second and third trimester are positive, much smaller in magnitude but not significant at any conventional levels. This is in line with findings elsewhere in the literature that stress induced by extreme events matters mostly during the first trimester of gestation (Camacho, 2008; Torche, 2011; Mansour and Rees, 2012).

Column (2) controls for a very rich set of mother and child characteristics and time-varying municipality characteristics from census data (see notes to Table 2), including municipality-specific linear time trends and municipality x calendar month (January to December) effects. Results are essentially unchanged relative to column (1), lending credibility to the identification assumption that—conditional on time- and municipality-fixed effects—the variation in the homicide rate across municipalities and time is almost as good as random. In column (3), we additionally include homicide rates in the fourth, fifth, and sixth trimester since conception, that is—for pregnancies of normal gestational length—in the first, second, and third trimester since birth and homicide rates in the three trimesters before conception. The inclusion of these variables makes virtually no difference to the results while we find no significant coefficients on the different lead and lag variables, lending support to our identification assumption. Figure 3 plots the point estimate and 95 percent confidence interval of the effect of homicide rate on birthweight and low birthweight for the three trimesters prior to conception, and the six trimesters after conception. Only the coefficient for the first trimester in utero reveals a significant negative effect, while the point estimates for the other quarters are much smaller and not significant.

Results in the following columns of the table confirm these findings and show that homicides have a particularly pronounced effect at the bottom tail of the birthweight distribution. We find significant effect of homicides in the first trimester the fraction of low, very low, and extremely low-weight births of, respectively, 0.17, 0.06, and 0.04 per 1,000 births. In turn this means that one extra homicide in a small municipality will lead to an increase in the fraction of low, very low, and extremely low birthweight children of 0.5 (=(0.17/10) X 100,000 / 3,700), 0.2 and 0.1 percentage points, that is, respectively a 6, 16, and 21 percent increase (relative to a baseline incidence of 0.078, 0.010, and 0.005).

5.2 Additional Outcomes

Table 3 reports regression results on a number of additional outcomes. For brevity, we report only specifications with the entire set of controls as in column (2) of Table 2. Column (1) reports the effect of homicides on gestational length. Indeed, homicides in the first trimester increase prematurity, by lowering gestational length. Column (2) reports the effect on APGAR scores. We use the average score one minute and five minutes post birth in an attempt to boost precision: still we find no evidence of a significant effect of increased levels of violence on this outcome.

Columns (3) to (6) report the effects on mortality rates at different intervals since birth. The dependent variable here is the fraction of deaths per thousand children born alive. Again, there is no evidence of violence affecting child mortality rates.

Columns (7) and (8) report estimates of impact on birthweight and low birthweight only for pregnancies of normal gestational length, defined as pregnancies of 37 weeks or more. We report results on birthweight and the fraction of low-birthweight children (as in columns (2) and (5) of Table 2). Interestingly, results on birthweight disappear. Combined with the findings in column (3) of Table 3, this suggests that violence leads to greater rates of prematurity and, via this, to increased risk of low birthweight.

The last concern we have pertains to selective fertility. Violence might affect birth outcomes through the selection that it operates on the number of children who are eventually born. This can happen through a variety of margins: selective sexual activity or contraception use, selective fetal mortality, abortion, and miscarriage. In order to study these combined effects, in column (9) of Table 3 we report a regression of the log number of births by municipality and time on the same variables as in columns (1) to (8) with the exception of mother characteristics. As in the other regressions, we control for the age and gender structure of the population in each municipality X time cell. The latter allows us to control for differences in the population at risk (women of fertile age) across cells. We find very small and statistically insignificant effects on fertility, implying that selection along this margin is unlikely to explain our results.

5.3 Alternative Definitions of Homicide

In Tables 2 and 3, we restrict reporting to homicides for which the death occurred in the street. Table 4 reports results using, respectively, homicides on the street and in one's residence (columns (1) to (5)) and all homicides, that is, also those for which death occurred in health institutions (columns (6) to (10)). Using additionally homicides for which the death occurred in residences makes virtually no difference to our results. Estimates, however, become smaller and less precise when we use all homicides: this is consistent with the notion that homicides for which the death occurred in hospital provide an error-ridden measure of local violence.

5.4 Heterogeneous Effects by Mother's Education

To conclude, in Table 5 we report separate regression results for infants born to mothers with incomplete and complete primary education (8 years of schooling) respectively. Each of these two groups account, roughly, for 50 percent of births. The effect seems to manifest largely among children of poorly educated mothers. Although results for highly educated mothers are qualitatively similar, point estimates are typically smaller and statistical significance is lower. It appears that violence adds up to the disadvantage that children of poorly educated mothers already suffer as a result of their household's lower socioeconomic status.

6. Summary of Findings and Conclusions

Using a very rich dataset on the universe of births and homicides from vital statistics data over the period 2000-2010, we estimate the effect of in-utero exposure to homicides on a range of birth outcomes in small Brazilian municipalities. We find a significant negative effect of exposure to violence during the first trimester on birthweight, which is in line with findings on the effect of other stress-related shocks during pregnancy in the literature. We also find significant and large positive effects of homicides on the probability of low birthweight, implying that the effects are particularly pronounced at the bottom tail of the birthweight distribution. Our results are robust to the introduction of maternal and municipal socioeconomic controls, including municipality-specific linear time trends. A falsification exercise, consisting of testing for the effect of pre- and post-pregnancy homicide rates on birth outcomes, lends further credibility to our identification assumption.

We show that violence in the first trimester of pregnancy affects birth outcomes through reduced gestational length. Increased prematurity hence, rather than intrauterine growth retardation, seems to explain the pronounced effect on low birthweight that we have documented in the paper.

As violence might affect the probability of appearing in the data set through changes in fertility or possibly via abortion or miscarriage, one concern in that our results might be driven by selection. That is, there may be a differential response to increased levels of violence among women with differential propensity to give birth to low-weight infants. Despite this concern, we find no evidence of homicides affecting fertility outcomes.

Finally, we show that results are largely concentrated among poorly educated mothers, that is, those with less than completed primary education. This suggests that violence adds up to the mechanisms that affect the transmission of socioeconomic status between parents and their offspring.

Although our estimates for the effect of one extra homicide in small municipalities are economically meaningful, high homicide rates are not responsible for the high level of low birthweight in Brazil. This is because overall, homicides are rather rare events. At current rates, and if one is willing to extrapolate the estimates from small municipalities to the whole of Brazil, our back-of-the-envelope calculations show that homicide rates account only for a minimal fraction (0.01 percent) of total low-birthweight incidence in the country.

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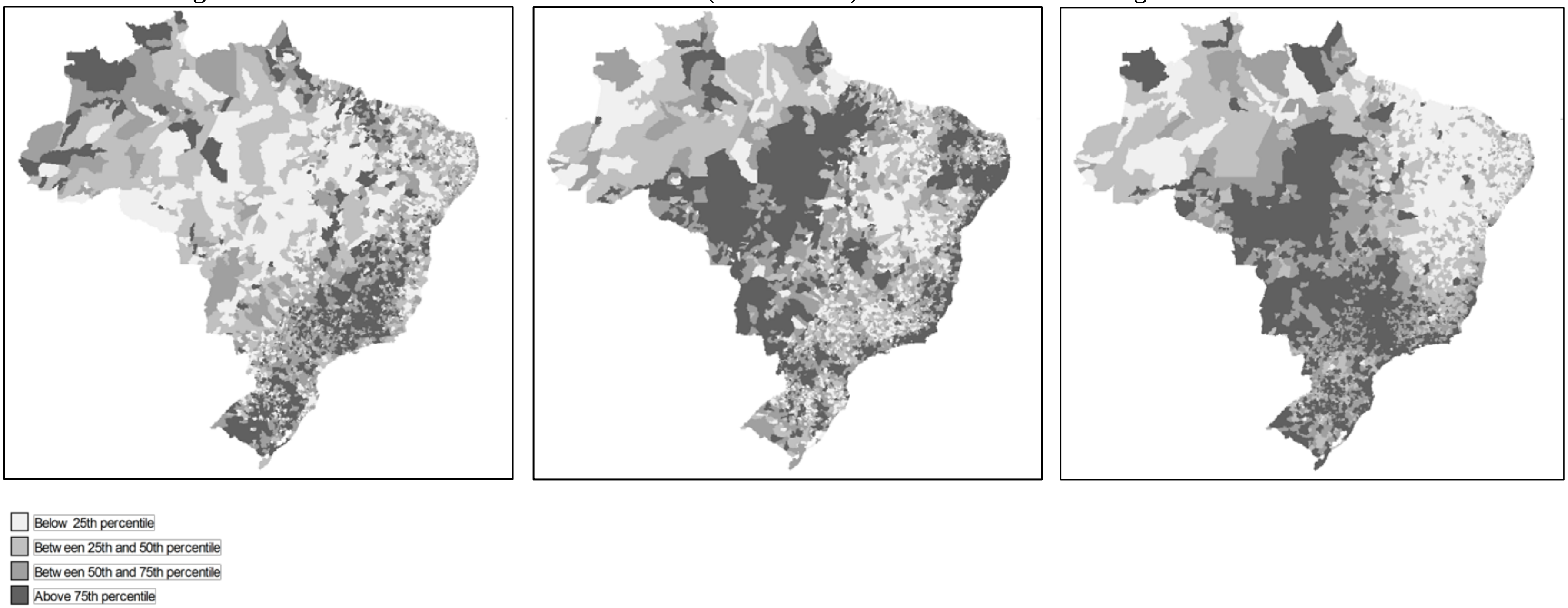
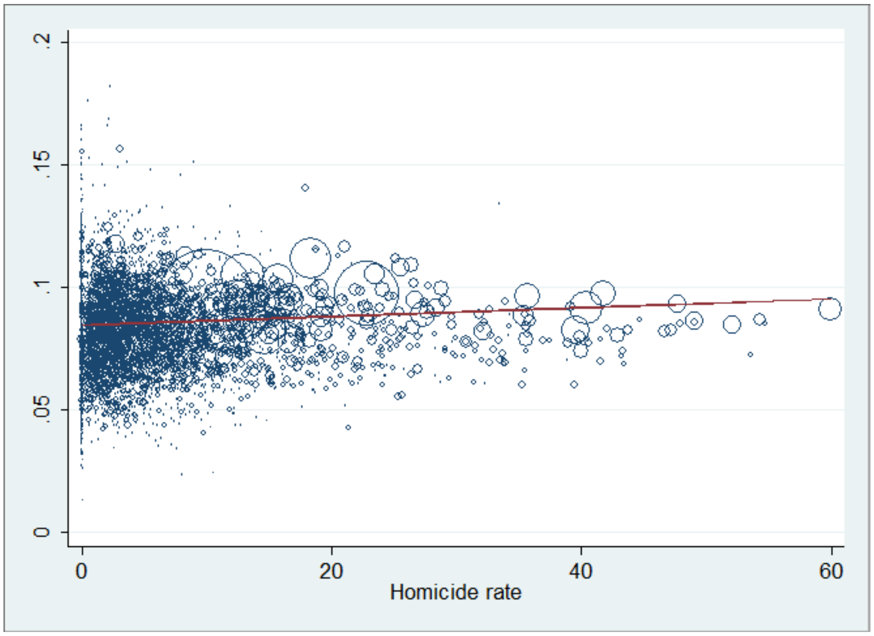
Figure 1. Municipality Characteristics

Fraction low-weight births | Homicide rate (on the street) | Average household income



Notes. The pictures report, respectively, the average fraction low-weight births (<2.5 kg), the homicide rate in public places, and household income between 2000 and 2010.

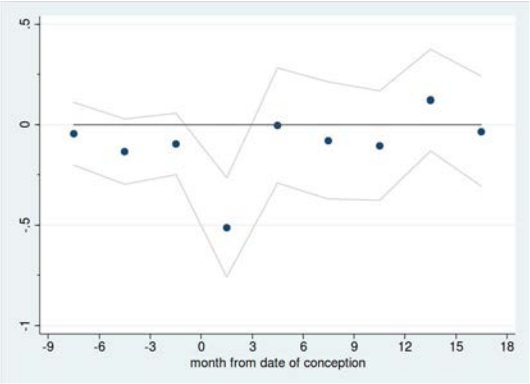
Figure 2: Incidence of Low Birthweight and Homicide Rates across Municipalities



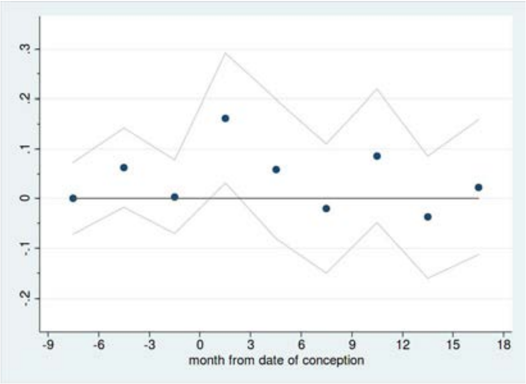
Note: The figure reports the relationship between the fraction of low-weight births and the annual homicide rate (in the street) across all Brazilian municipalities. A predicted regression line is superimposed and larger circles correspond to larger cities.

Figure 3. Effect on Outcomes by Trimester since Conception

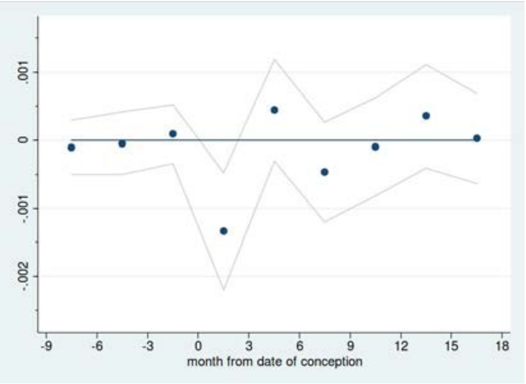
Birthweight (g.)



Low birthweight (<2.500 g)



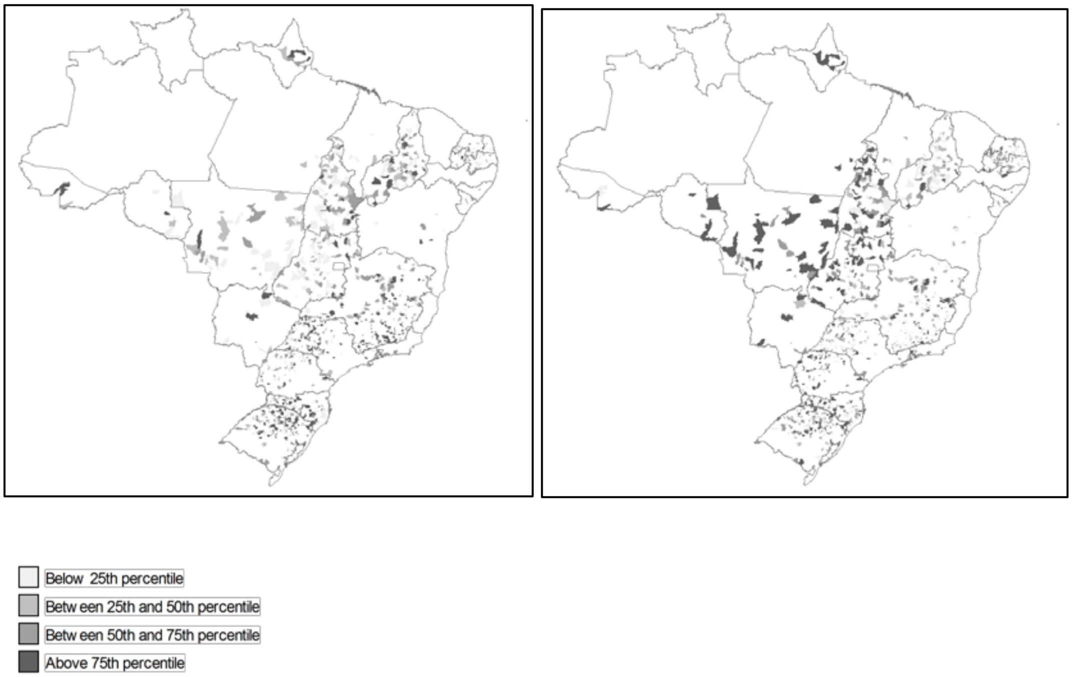
Gestational length (weeks)



Note: The picture reports estimated effects of local homicide rate at different points before, during and after pregnancy. Trimesters are expressed since (from) the date of conception denoted by 0.

Figure 4. Small Municipality Characteristics

Fraction low-weight births | Homicide rate (on the street)



Note: The pictures report, respectively, the average fraction low-weight births (<2.5 kg) and the homicide rate in public places for municipalities of average size no greater than 5,000 inhabitants.

Table 1. Descriptive Statistics

	All	By municipality size				
		<5000	5,000-19,999	20,000-99,999	100,001-500,000	>500,000
Number of municipalities	5,508	1,289	2,648	1,320	215	36
Number of births	30,367,939	616,733	4,491,073	8,808,710	7,254,770	9,106,653
Birthweight	3184.190	3,210.62	3,222.315	3,207.675	3,164.246	3,156.751
Low birthweight	0.087	0.078	0.080	0.082	0.092	0.082
Very low birthweight	0.012	0.010	0.011	0.011	0.013	0.011
Extremely low birthweight	0.006	0.005	0.005	0.005	0.006	0.004
Gestational length	38.690	38.751	38.755	38.748	38.659	38.622
APGAR – 1 minute	8.144	8.143	8.073	8.109	8.185	8.176
APGAR – 5 minutes	9.235	9.300	9.226	9.242	9.250	9.216
Female	0.512	0.514	0.513	0.513	0.512	0.512
White	0.502	0.598	0.471	0.459	0.561	0.508
Prenatal visits	5.705	5.803	5.446	5.458	5.889	5.920
Mother's age	26.168	26.022	26.223	25.744	25.933	26.754
Mother never married	0.613	0.563	0.633	0.657	0.622	0.601
Mother's years of schooling	7.826	7.745	7.256	7.695	8.865	7.736
Early neonatal mortality (1 wk.)	9.121	8.000	8.832	9.110	11.881	7.042
Neonatal mortality (4 wks.)	11.211	9.767	10.625	10.901	14.486	9.184
Perinatal mortality (22 wks.)	13.595	11.973	13.129	13.441	16.923	11.316
Infant mortality (1 year)	14.706	12.951	14.446	14.746	17.986	12.170
Homicide rate	26.284	9.102	12.832	19.381	32.650	36.613
Homicide rate, on the street	10.972	2.498	4.284	7.903	14.574	15.330
Homicide rate, on the street and in homes	13.888	4.691	6.855	10.794	17.999	18.067
Population	1,170,281	3,703	12,638	49,120	250,081	3,887,465
Urbanization rate	0.822	0.531	0.574	0.721	0.937	0.984
HH income 2010 $R	1,100.41	582.53	571.05	752.81	1,150.36	1,663.70
Literacy rate	0.817	0.758	0.723	0.755	0.848	0.878

Source: DATASUS and IBGE population census.
Notes: All entries are weighted by the number of births. Neonatal and infant mortality rates are expressed as a fraction per 1,000 live births. Homicide rates are expressed as a fraction per 100,000 population.

Table 2. The Effect of Homicides during Pregnancy on Birthweight by Trimester since Conception, Small Municipalities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Trimester	Birthweight (grams)			Low birthweight (x 1,000)			Very low birthweight (x 1,000)			Extremely low birthweight (x 1,000)		
1 (pre-conception)			-0.0439			0.0011			-0.0161			-0.0081
			(0.1037)			(0.0480)			(0.0184)			(0.0121)
2 (pre-conception)			-0.1344			0.0621			0.0322			0.0279*
			(0.1090)			(0.0531)			(0.0232)			(0.0151)
3 (pre-conception)			-0.0954			0.0036			0.0006			-0.0123
			(0.1021)			(0.0494)			(0.0191)			(0.0111)
1	-0.4328**	-0.4506***	-0.4551***	0.1488*	0.1680**	0.1709**	0.05563	0.0580*	0.0593*	0.0403	0.0393	0.0416*
	(0.1722)	(0.1627)	(0.1625)	(0.0890)	(0.0836)	(0.0839)	(0.0354)	(0.0344)	(0.0342)	(0.0258)	(0.0256)	(0.0252)
2	0.0192	0.0568	0.0507	0.0688	0.0584	0.0624	-0.0310	-0.0356	-0.0336	-0.0149	-0.0209	-0.0183
	(0.2030)	(0.1918)	(0.1920)	(0.0956)	(0.0890)	(0.0891)	(0.0342)	(0.0337)	(0.0337)	(0.0240)	(0.0242)	(0.0240)
3	0.0214	-0.0486	-0.0523	-0.0272	0.0038	0.0059	0.0399	0.0407	0.0418	0.0221	0.0194	0.0212
	(0.1967)	(0.1885)	(0.1904)	(0.0882)	(0.0859)	(0.0862)	(0.0415)	(0.0408)	(0.0414)	(0.0315)	(0.0305)	(0.0313)
4 (post-birth)			-0.0946			0.0513			0.0380			0.0285
			(0.1802)			(0.0850)			(0.0380)			(0.0314)
5 (post-birth)			-0.0313			0.0095			0.0056			0.0271
			(0.1898)			(0.0842)			(0.0459)			(0.0373)
6 (post-birth)			-0.1005			0.0806			0.0286			0.0480
			(0.2086)			(0.0944)			(0.0402)			(0.0373)
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pregnancy controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Mother controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Municipality controls	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes

Notes: Each column reports the results from a separate regression of the dependent variable on the local quarterly homicide rate in different trimesters since the month of conception. Homicide rates are expressed as fraction per 100,000 individuals. Fraction birthweight is expressed per 1,000 live births. Regressions are run on cells defined by municipality and time of conception with weights equal to the number of births by cell. Controls include number of newborns by gender and race (black, white, mixed, Asian, indigenous) and number of multiple births (twins, triplets, more than three children). Mother controls include age (10-19, 20-39, etc.), marital status (single, married, divorced, widowed), years of completed education (no education, 1-3, 4-7, 8-11, 12 and more), average number of previously born alive children and of stillbirths. Municipality controls include fraction of households with possession of radio, TV, washing machine, telephone, computer, and fraction with access to piped water, waste collection, electricity, fraction of the population by gender and age, fraction of adult population literate, average years of schooling in the population, fraction of families with *Bolsa Família*, health establishments and nurses per capita, unemployment rate, urbanization rate, fraction of children in work, interaction of municipality with calendar month and municipality trends. Clustered standard errors by municipality in parentheses.
*** p<0.01, ** p<0.05, * p<0.1. Number of cell observations: 136,711 (616,733 births).

Table 3. Homicide Rates and Additional Birth Outcomes by Trimester since Conception, Small Municipalities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Gestational length (weeks)	APGAR score (avg. 1 & 5 minutes)	Child mortality rates (x 1,000)				Only pregnancies of normal gestation length (37 weeks or more)		Log number of births
Trimester			Early neonatal (1 week)	Neonatal (4 weeks)	Perinatal (22 weeks)	Infant (1 year)	Weight	Low birthweight (x 1,000)	
1	-0.0011*	-0.1199	-0.0384	0.0201	0.0510	0.0872	-0.1877	0.0884	0.0001
	(0.0005)	(0.4685)	(0.1131)	(0.1345)	(0.1558)	(0.1599)	(0.1558)	(0.0689)	(0.0001)
2	0.0004	0.1905	0.1190	0.0754	0.1512	0.1197	-0.0073	0.0519	-0.0000
	(0.0005)	(0.4673)	(0.1289)	(0.1379)	(0.1468)	(0.1558)	(0.1860)	(0.0731)	(0.0001)
3	-0.0005	-0.1657	0.0410	-0.0415	-0.0500	-0.0874	0.0541	-0.0560	-0.0001
	(0.0005)	(0.4851)	(0.1148)	(0.1190)	(0.1376)	(0.1330)	(0.1796)	(0.0739)	(0.0001)
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pregnancy controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Mother controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable in columns 3 to 6 is fraction of children dead per 1,000 live births. See also notes to Table 2.

Table 4. The Effect of Homicides during Pregnancy on Birthweight by Trimester since Conception, Alternative Definition of Homicide Rate, Small Municipalities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Homicides in the street and in one's home					All homicides				
Trimester	Birthweight (grams)	Low birthweight (x 1,000)	Very low birthweight (x 1,000)	Extremely low birthweight (x 1,000)	Gestational length (weeks)	Birthweight (grams)	Low birthweight (x 1,000)	Very low birthweight (x 1,000)	Extremely low birthweight (x 1,000)	Gestational length (weeks)
1	-0.3308***	0.0816	0.0588**	0.0480**	-0.0007*	-0.1674*	0.0156	0.0179	0.0177	-0.0002
	(0.1250)	(0.0616)	(0.0279)	(0.0218)	(0.0004)	(0.0904)	(0.0464)	(0.0193)	(0.0143)	(0.0003)
2	-0.0039	0.0731	-0.0206	-0.0113	0.0004	-0.0133	0.0259	-0.0329*	-0.0226	0.0005*
	(0.1331)	(0.0619)	(0.0247)	(0.0196)	(0.0003)	(0.1070)	(0.0499)	(0.0183)	(0.0141)	(0.0003)
3	-0.0272	0.0046	0.0309	0.0170	-0.0002	0.0327	-0.0380	0.0054	-0.0019	-0.0001
	(0.1389)	(0.0635)	(0.0277)	(0.0203)	(0.0003)	(0.1003)	(0.0487)	(0.0198)	(0.0146)	(0.0003)
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pregnancy controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: See also notes to Table 2.

Table 5. Homicide Rates and Additional Birth Outcomes by Trimester since Conception, by Mother's Education, Small Municipalities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Incomplete primary education				Completed primary education			
Trimester	Birthweight (grams)	Low birthweight (x 1,000)	Gestational length (weeks)	APGAR score (avg. 1 & 5 minutes)	Birthweight (grams)	Low birthweight (x 1,000)	Gestational length (weeks)	APGAR score (avg. 1 & 5 minutes)
1	-0.4738**	0.1630	-0.0011	-0.2976	-0.2775	0.1208	-0.0008	0.1086
	(0.2182)	(0.1188)	(0.0007)	(0.6173)	(0.2608)	(0.1221)	(0.0008)	(0.5834)
2	0.1104	0.1224	0.0009	0.1349	-0.1116	-0.0546	0.0001	0.5817
	(0.2427)	(0.1148)	(0.0006)	(0.5814)	(0.2748)	(0.1288)	(0.0008)	(0.5922)
3	-0.0325	-0.0941	-0.0003	0.3337	-0.1436	0.1725	-0.0007	-0.7016
	(0.2521)	(0.1140)	(0.0006)	(0.6216)	(0.2557)	(0.1208)	(0.0007)	(0.5512)
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pregnancy controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Incomplete primary education corresponds to less than 8 years of completed education. Number of observations in columns 1 to 4 is 115,922, while in columns 5 to 8 this is 109,510. See also notes to Table 2.

Table A1. The Effect of Homicides during Pregnancy on Birthweight by Trimester since Conception, by Municipality Size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Trimester	5,001-20,000		20,001-100,000		100,001-500,000		>500,000	
1 (pre conception)		-0.0109		-0.0174		0.0769		-0.2723
		(0.0648)		(0.0657)		(0.1302)		(0.3754)
2 (pre conception)		-0.0131		-0.0562		0.0885		-0.3816*
		(0.0573)		(0.0718)		(0.1144)		(0.2226)
3 (pre conception)		-0.0314		0.0629		0.0570		0.1392
		(0.0605)		(0.0792)		(0.1208)		(0.3214)
1	0.0911	0.1296	-0.1452	-0.0399	0.903	0.0209	0.3289	0.9670**
	(0.0990)	(0.0934)	(0.1089)	(0.1038)	(0.2118)	(0.1864)	(0.4537)	(0.3554)
2	-0.0702	-0.0525	-0.0267	0.1531	0.1720	-0.0531	0.0187	0.0359
	(0.1047)	(0.0984)	(0.1112)	(0.1042)	(0.2118)	(0.1894)	(0.3572)	(0.3491)
3	0.0563	0.0597	-0.0570	-0.0147	-0.2779	-0.2898	-1.3954***	-1.0908**
	(0.1001)	(0.0965)	(0.1155)	(0.0990)	(0.1842)	(0.1771)	(0.4345)	(0.4561)
4 (post birth)		-0.0474		-0.1782*		-0.2064		0.3185
		(0.0985)		(0.0948)		(0.1601)		(0.4327)
5 (post birth)		0.0676		-0.1233		0.0590		0.0417
		(0.0975)		(0.0940)		(0.1649)		(0.4859)
6 (post birth)		0.0686		-0.0560		-0.1838		-0.1287
		(0.0966)		(0.0965)		(0.1473)		(0.5735)
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pregnancy controls	No	Yes	No	Yes	No	Yes	No	Yes
Mother controls	No	Yes	No	Yes	No	Yes	No	Yes
Municipality controls	No	Yes	No	Yes	No	Yes	No	Yes
Number of cell observations	300,436	300,436	150,358	150,358	24,500	24,500	3,978	3,978
Number of individuals observations	4,491,073	4,491,073	8,808,710	8,808,710	7,254,770	7,254,770	9,106,653	9,106,653

Note: See notes of Table 2.