UNIVERSITAT DE BARCELONA

Essays on Development Economics

Henry Bernard Moscoso Miranda

PhD in Economics

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“*Ser más, para servir mejor*”.

San Ignacio de Loyola.

“*Solo hace falta una sola presencia, una entre millones, solo una necesaria, para que lo invisible converja, permanezca y sea.*”

Bernard Moscoso

A Dios, por darme la vida y la vocación que se me ha encomendado

A mi Madre, ejemplar, quien me inspira siempre a ser mejor

A mi Hermana y mis Hermanos

A la memoria de mi Abuelo y de mi Padre

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Thank you.

Table of Contents

List of Tables

Chapter 2

Chapter 3

Chapter 4

List of Figures

Introduction

Chapter 2

Chapter 3

Chapter 4

1 Chapter 1 – Introduction

Development economics seeks to provide evidence to improve life quality standards of the societies. This thesis contributes to this field with a multidisciplinary research on health, environmental and crime economics. This essay is composed of 3 academic papers that analyze actual social problems that have received little attention by policy makers and scholars, and that are negatively affecting newborns health and women wellbeing, in the context of Ecuador.

Why health at birth should be studied in economics? The reason to study health at birth is that newborns health is found to be one of the key determinants for long-run socio-economic outcomes. As Almond, Currie, and Duque (2018) argue, the relevance of the studies on newborn health stands on the fetal origin hypothesis, first formulated by Barker (1998) in his study on prenatal nutritional deprivation on health conditions in the adulthood. The main idea of this hypothesis is that a wide range of early life experiences matter and that many other (non-health) outcomes are affected. Since then, the fetal origin hypothesis has analyzed how different circumstances that affects in-utero formation environment have effects in human capital formation in the short and the long-run (Currie and Hyson, 1999; Costa, 2000; Almond, 2006). Two of the three academic papers of this thesis stand over this literature and contributes with new evidence to understand two aspects that threatens the health at birth, such as environmental pollution of pesticides, and the indirect exposure to violent events.

Newborns' adverse health outcomes have negative consequences in their first years of life and during their childhood and adulthood. According to the Global Burden of Disease Collaborative Network (2018), nearly 12% of the mortality of children under the age of five in the world are due to disorders during fetal growth and outcomes at birth. Similarly, the World Health Organization (2019) has emphasized that the weight at birth is crucial for the newborn survival and healthy growth after birth. Moreover, pre-term gestations and low birth weight are associated with birth deficits such as high risk of having underdeveloped organ failures, vulnerability to attract infectious diseases, other birth injuries. Furthermore, negative impacts on the Apgar score[1] have been related with future cognitive function deficiencies, affecting both schooling and labor market outcomes.

[1] The Apgar score at the first minute assesses fetal health at birth on a 0-10 scale observing the newborns' appearance (skin color), pulse (heart rate), grimace function (reflexes), activity (muscle tone), and respiration (breathing rate and effort).

What is the state of the art, and how is this essay contributing to the literature? The pivotal economic literature has shown the relevance of studying the impact of different types of externalities on health at birth and infant health (Barker, 1995; Almond et al., 2005; Black et al., 2007; Almond and Currie, 2011; Almond, Currie, and Duque, 2018). Social problems such as insecurity or environment pollution play a fundamental role in the newborns' growing environment. Nowadays, there is a wide evidence on the consequences that adverse environmental externalities received during intra-uterine growth generate in the future development and living conditions of the population, affecting relevant aspects like their cognitive ability, psychological and personality traits, scholarity, and wages (Currie and Vogl, 2013; Bharadwaj et al., 2013; Almond, Currie, and Duque, 2018). Similarly, there is a growing empirical evidence on the negative consequences of insecurity and crime on infant cognitive capacity and human capital formation (Duque, 2017; Sharkey et al., 2012). Moreover, violence generates psychological stress to those individuals who are directly or indirectly exposed to it (Aizer, 2016; Koppensteiner and Manacorda, 2016; Currie et al., 2020).

This thesis contributes to this literature examining three relevant problems that affects the population of Ecuador: environmental pollution due to the use of pesticides in agriculture; maternal stress due to violent crimes, and violence against women. Moreover, each chapter provides strong evidence to address future public policy design. The second chapter of the thesis examines the effects of the use of pesticides in the banana plantations of Ecuador on newborns' health outcomes. The results drawn from this research reveal that the exposure to the intensive use of pesticides leads to a deficit in the birth weight when the exposure occurs during the first trimester of gestation. Moreover, exposure to intensive use of pesticides during the last gestation stage increases the likelihood of low birth weight and low Apgar score at first minute. The third chapter of the thesis reveals the existence of a retaliation effect after a reform of the penal code in 2014 that increased the penalties for gender-related violence and that introduce the *femicide* penalty type. I show that this legislative reform, and its enforcement, led to a (temporally) increase in the women victimization rates. The fourth chapter of this thesis examines the effects of the maternal stress generated by violent crimes on newborns' health outcomes. The results obtained from this research reveal that mothers' indirect exposure to homicides during pregnancy causes a deficit in the birth weight, which is especially important when this exposure occurs during the first trimester of gestation. Moreover, I demonstrate that mothers' past exposure to violent crimes attenuates the effects of homicides during pregnancy. Furthermore, the exposure to homicides during the last gestation term reduces gestation length and the Apgar score at the first minute.

The rest of this introduction offers a more extensive motivation of the three research chapters of the thesis, followed by a brief description of the data and the empirical strategies, and the main results and contributions.

Chapter 2. The first research objective of my thesis is to analyze the health implications of the use of pesticides in agriculture. The second chapter of my thesis has the title "*The hidden cost of bananas: pesticide effects on newborns' health*" [2] and it examines the effects of the air fumigations of banana plantations in Ecuador on newborns' health outcomes.

Motivation. This chapter examines the effects of the use of pesticides in agriculture on newborns' health. My interest on this topic arises due to the civil protests and public questioning on the use of aerial fumigation of banana plantations in Ecuador, and in the plantations of many other crops in many other agricultural intensive economies. Ecuador is one of the countries with the highest use of pesticides per hectares of cropland in the world. Figure 1.1 shows the average use of pesticides per hectare in the world in 2017. In particular, in 2017 Ecuador employed nearly 14 kilograms of pesticides per hectare. Moreover, the Environmental Repair Program of the Ministry of Environment in Ecuador reveals that in 2014 the banana farms employed nearly 3.5 million gallons of agrochemicals sprayed through aerial fumigations.

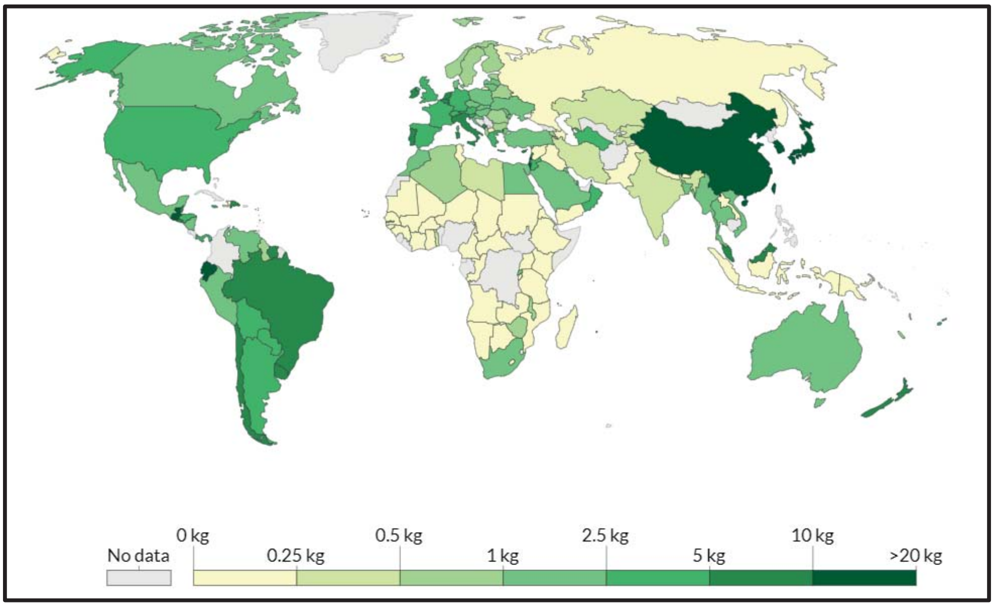
This chapter analyzes the effects of aerial fumigation of banana plantations on newborns' health outcomes during the period 2015-2017 in Ecuador. In Ecuador, there are around 7.5 thousand banana farms and nearly 85% of them use aerial fumigations to treat the fungal disease known as *Sigatoka Negra*. This fungus can cause severe damage in the entire banana plantations, by progressively destroying the foliage and affecting the photosynthetic process. This causes the fruits to shrink or die after the blossoming stage. One aspect that is relevant for this study, is that the spread of this fungus depends on the rain and humidity conditions of the winter season (Khan et al., 2015). For this reason, producers intensify aerial fumigations of pesticides in this season.

The uses of pesticides in the fumigations can cause important health effects in the neighboring population, such as high toxic levels inhalation affecting body functions (Friedman et al., 2020). This problem has received vast attention not only in Ecuador, but also in France, Spain, the United States of America, Argentina, and other economies with high levels of agricultural activity. In Ecuador, the government has introduced several regulations in the years 2012 and 2015 that stipulate a security distance from *aerial fumigation* sites to households and public spaces. Other regulation has stablished that the plantations can be fumigated only under several weather conditions. Notwithstanding, these distance

[2] Co-authored with Joan Calzada and Meritxell Gisbert.

regulations have negative consequences for banana producers who must increase the cost of pesticides applied manually. In addition, these measures may adversely face moral hazard problems, as the non-compliance and unregulated fumigation activity. Therefore, very little is known about the effectiveness of these measures and about the ability of the authorities to enforce its compliance.

Figure 1.1 – Pesticide use per hectare of cropland in the world, in 2017 (kilograms per hectare).



Source: UN Food and Agricultural Organization (FAO), retrieved from Our World in Data Organization.

The production and exports of banana are key to the Ecuadorian GDP. Indeed, Ecuador is the fifth largest producer and the largest exporter of bananas in the world. Since many decades ago, local producers have dedicated strong efforts to ameliorate the production rates with the employment of agrochemicals on a massive scale at different stages of the production process (FAO, 2016). Meanwhile, an increasing number of medical and environmental studies have found higher pesticide concentrations in blood and urine tests, and in both outdoor and indoor surface deposition of chlorpyrifos, in residences located within 60 meters, 100 meters and up to 250 meters of agricultural fields (Coronado et al., 2011; van Wendel de Joode et al., 2012; Deziel et al., 2017; Gibbs et al., 2017; Dereumeaux et al., 2020). These studies have found that the consequences of being exposed to these toxics are, among others, intra-uterine growth restrictions, low birth weight, small cranial circumference, and low average neurobehavioral performance at birth (Rauh et al., 2006; Friedman et al., 2020).

Background. This chapter contributes to the growing body of literature that studies the consequences of air pollution on children's health. The economic research has shown that birth weight, gestational length, and in utero survival are all affected by industrial activity (Hansman et al., 2019), environmental regulations (Greenstone and Hanna, 2014; Tanaka, 2015), major forest fires (Frankenberg, McKee, and Thomas, 2012; Tan-Soo and Pattanayak, 2019), agricultural fires (Rangel and Vogl, 2019) and indoor pollution (Hanna, Duflo and Greenstone, 2016; Barron and Torero, 2017). In spite of this, there are few studies analyzing the effects of the intensive use of pesticides in agriculture (some exceptions are Camacho and Mejia, 2017; Larsen et al., 2017; Dias et al., 2019; Maertens, 2019; Jones, 2020). Farms around the world use pesticides to fight against fungus, pests, and crop disease, but in order to regulate these activities it is important to understand the causal effect of exposure to pesticides on health outcomes for workers and the neighboring population.

Data and empirical strategy. In order to examine the impact of the pesticides on health at birth, this chapter focuses on the coastal region of Ecuador, where banana plantations are present across 5 provinces, and in nearly 140 municipalities. We identify almost 7 thousand banana farms from which almost the 70% uses aerial fumigation to protect their crops from pests and fungus diseases. Our study draws on a public data set obtained from the National Register of Live Births (*Registro estadístico de nacidos vivos*) for the period 2015-2017, which contains information for nearly 270 thousand newborns and from which we obtained the mothers' residence addresses during pregnancy. Almost 51 thousand of these mothers resided within 2.5 kilometers of the banana plantations, which is the distance we use to compute buffers that measure newborns' exposition to pesticides. This data set includes information on several observable characteristics of children and mothers. We complement this information with a data set on Ecuador's banana plantations from the 2013 agricultural census and the 2014 register of aerial fumigations. The former contains information on the perimeter of each plantation and the use of aerial or manual fumigations, and the latter contains geocoded data on the application of pesticides (i.e., quantity, toxicity, date of application). We combine the information on the mothers' locations, the perimeters of the plantations and the use of pesticides to calculate several measures that reflect the exposure of each individual newborn to pesticides.

We implement three different empirical designs to analyze the causal effects of pesticides on newborns' health. First, we exploit the seasonal changes in the intensity of fumigations across provinces. Banana plantations are fumigated over the whole year, but fumigations are more intense during the rainy season, which is when the *Sigatoka Negra* fungus propagates more easily. Taking this into account, we use seasonal fumigation patterns across provinces to estimate a difference-in-differences (DID) model that compares the difference between newborns living in exposed areas in intense and non-intense fumigations seasons, relative to the difference between newborns living in not exposed areas in the same two seasons. Our second identification strategy estimates a DID approach that compares the difference between newborns exposed and not exposed to fumigated banana plantations, relative to the difference between newborns exposed and not exposed to any other crops. This analysis is based on the fact that other crops (such as rice, cocoa, and corn) produced in Ecuador are fumigated much less intensively than banana plantations and on the assumption that in each municipality the population living close to banana plantations and living close to the other crops are not statistically different. Finally, we complement the previous analysis with the estimation of a maternal fixed-effects model, for a sample of mothers that had more than one child during the period we analyze. In the years 2015-2017, a relevant percentage of mothers in our data set moved to a different address, which allows us to analyze the difference in birth weight between siblings exposed and not exposed to pesticides during gestation.

Main results. The main findings of this paper can be summarized as follows. The seasonal intensification of fumigations analysis reveals that exposure to pesticides have a statistically significant negative impact on newborns' birth weight when the first trimester of gestation undergoes in the months of intensive fumigations. Specifically, newborns exposed to pesticides have a birth weight deficit of between 39 and 89 grams if their first trimester of gestation coincides with the seasons of intensive fumigations. Further results from this estimation suggest that the exposure to the intensive use of pesticides leads to a higher likelihood of low Apgar score at the first minute, and preterm delivery, when the exposure occurs during the third trimester of gestation. These estimates reflect the effect of the seasonal intensification of fumigations, so the overall impact of pesticides on newborns health outcomes is expected to be higher. The second analysis exploits the spatial variation in newborns' exposure to the fumigation of banana plantations and to the fumigation of other crops (rice, corn, cocoa). The results suggest that exposure to fumigation of banana plantations generates a birth weight deficit of between 29 and 76 grams, compared to newborns whose mothers are exposed to the fumigation other crops.

The effects are larger for newborn girls and for those born to mothers with less schooling education. Finally, the maternal fixed-effects estimation reveals that newborn girls exposed in utero to pesticides have a birth weight deficit of around 250 grams, compared to their non-exposed female sibling. One explanation for the great size of the effect is that high exposure to pesticides in pregnancy shortens the gestation period by an average of 2 weeks.

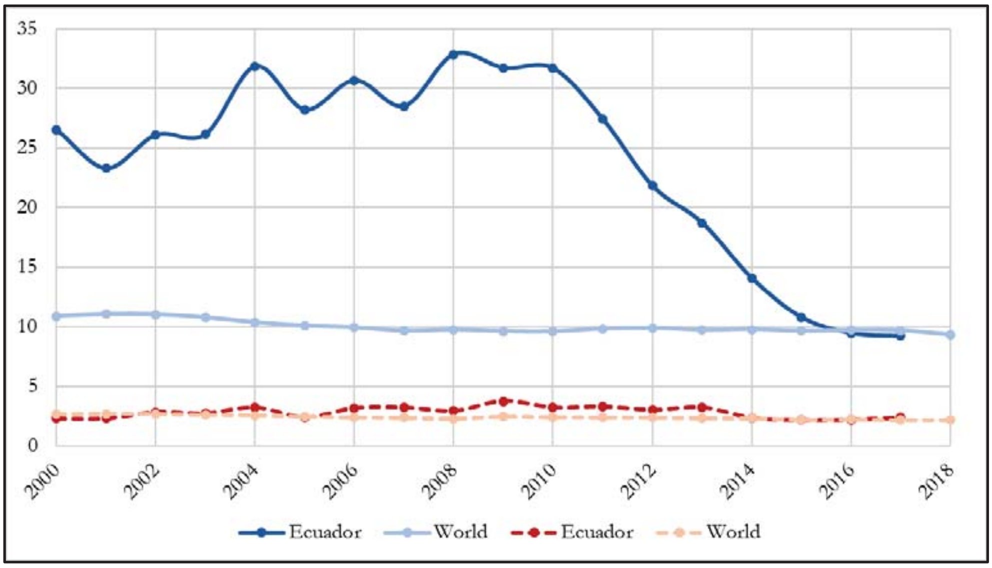
Contribution and policy implications. The results of this chapter are in accordance with the findings in medical and environmental papers that examine the effects of pollutants on health at birth. Our effects are much larger than the 30 grams obtained by Bozzoli and Quintana-Domeque (2014), when they analyzed the effects of the economic crisis in Argentina, or the 23 grams found by Range and Vogl (2019), who examined the effects of the fire pollution caused by sugar cane harvesting in Brazil. However, our findings are close to the 200-gram effect found for mothers that smoke (Kramer, 1987; Lindbohm et al., 2002) and to the 107-175-gram impact obtained by Burlando (2014) examining the consequences of an unexpected blackout in Tanzania. We also confirm the finding obtained in previous studies of air pollution showing a larger impact in the first trimester of gestation (Almond et al., 2011; Bozzoli and Quintana-Domeque, 2014; Burlando, 2014).

Our findings have relevant policy implications. Aerial pesticide fumigation plays a key role in the agriculture industry, but its massive and uncontrolled use is causing important health problems in nearby populations. Our paper contributes to the existing economic, medical, and environmental literature by examining the causal relationship between newborns' in-utero exposure to pesticides and adverse health outcomes. In order to do this, we combine precise information on mother's residence during pregnancy, the perimeter of banana plantations and the volume and frequency of pesticide use in Ecuador. We believe that this research can help to improve the design of public policies regarding fumigation practices in different plantations across the world and can be used to enhance pregnancy protocols in affected regions. Our conclusions reinforce the necessity to modify the use of agrochemicals in agriculture to protect the population living in the neighboring of the plantations and the workers. We have shown that in Ecuador, aerial fumigations have a very relevant impact on the health of newborns born in close proximity to the banana plantations. Thus, these results highlight the urgency of enforcing and reviewing the protection distances established in the country's legislation in 2012 and 2015, to safeguard the health of the population.

Chapter 3. The second research question examined in my thesis is whether or not the legislation reform adopted to penalize violence against women can lead to an increase of femicides, as a reaction against such measures. The title of the third chapter of my thesis is "*Femicides: laws, women empowerment, and retaliation effects*", and it examines the retaliation effects against the reform of the Ecuadorian penal code introduced in 2014 on the female homicides and gender-violence homicides rates.

Motivation. Gender violence and female homicides have been declared as a public health matter and represent a violation of women's human rights (World Health Organization, 2018). The magnitude of this problem has brought global action to include the mitigation of violence against women as one of the sustainable development goals (United Nations, 2015). However, eradication of violence against women faces socio-cultural challenges including gender inequalities, male rejection against women empowerment, and weak justice efforts to solve gender-violence crimes. In absolute numbers, it is estimated that a total of 87,000 women were intentionally killed in the world in 2017 (UNDOC, 2018). It has been estimated that nearly 34% of these women were intentionally killed by their intimate partner, but a big share of these crimes is unsolved, and the perpetrators have not been charged with the penalties corresponding to femicides (World Health Organization, 2018). Figure 1.2 provides a general view of the male and female homicides rates per 100,000 inhabitants in the world. The figure shows that in the world there are important differences in the number of male (plain lines) and female (dashed lines) homicides rate, and that the number of homicides per 100,000 inhabitants in the two genders has been quite stable in the last decades. In Ecuador, the male homicides rate has significantly decreased, while the female homicides rate has remained quite stable, showing nowadays slightly higher levels relative to the average world rate.

Figure 1.2 - Annual male and female homicide rate per 100,000 inhabitants (2000-21)



Note: The values for the male homicides per 100,000 inhabitants are represented with continuous lines curve, and the female values with dashed line curves.
Source: UN Office on Drugs and Crime's International Homicide Statistics database, retrieved by the World Development Indicators (World Bank).

Gender violence and homicides has many relevant consequences on the mental health of women and their child (Perez et al., 2016; Bonner et al., 2019). The psychological literature has examined the effect of crime and of intra-household violence on children's socio-economic outcomes in the future. Childhood adverse experiences on chaotic homes generate delinquency in the adulthood (DeLisi et al., 2017; Bonner et al., 2019) and prompts antisocial behavior which may turn into arrests, incarceration, or probation (Beaver et al., 2015). In particular, negative experiences during childhood have long-term negative effects on the behavioral functioning and antisocial development. Additionally, Perez et al. (2016) show that being exposed to adverse childhood experiences led to substance abuse, and to violent and chronic delinquency.

Violence against women is a latent problem in Ecuador, where one female homicide is reported each 2 to 3 days. More specifically, there is an average of 2.85 victims per 100,000 inhabitants for the period 2010-20. During the last decades, female homicides were considered as *homicide* or *assassination*, which implied that the perpetrator faced lesser years of prison. The severity of this problem led the government to introduce the *femicide* penalty type in a reform of the penal code that was approved in 2014.

Background. Female homicides and gender-violence have been associated with gender inequalities, women's access to resources including subsidies and wages, and emotional dependence to their partner (Bart and Moran, 1993). There are also studies showing that social interventions targeted to decrease gender gaps through employment and education may reduce gender-violence and intra-partner homicides rates (Dugan et al., 2003; Dawson et al., 2009; Eriksson and Mazerolle, 2013). There is also a number of papers showing that gender equality policies and legislative changes to penalize violence against women may have unexpected consequences and lead to (temporarily) increases of gender violence. This can be due to male/female stigma, social norms, and marital conflicts as a response against women empowerment (Dugan et al., 2003; Angelucci, 2008; Xie et al., 2012; Banerjee, La Ferrara and Orozco, 2019). This problem is known in the literature as the *retaliation effect*, or *backlash effect*.

In Ecuador, the new penal code included the *femicide* penal type for the first time, and it considers the highest of the penalties (up to 34 years of prison) to the gender-violence perpetrators. The main objective was to reduce violence against women. One important aspect of the new legislation is that it has not been enforced homogenously across all municipalities. This can be due to lack of criteria or training of judiciary authorities specialized on the female homicides or, in some cases, to the lack of effort on solving femicide cases. This impunity situation implies that the perpetrator does not receive an accurate sentence and can be related to socio-cultural norms that undermines the gender-violence (*Fiscalia General del Estado*, 2019). This provides a context to analyze for the retaliation effect hypothesis.

Data and empirical strategy. The objective of this paper is to study whether or not the reform of the Ecuadorian penal code in 2014 and the increase of women empowerment has generated a *retaliation effect*. To do so, I use information from the national homicides register of Ecuador gathered by the *Ministerio del Interior*. My study considers the period 2010-2020 since these are the years for which the homicides' geographical occurrence is available. My dataset includes information for nearly 14,000 homicides across the whole country during the period 2010-20. From these, about the 15.5% (N=2,167) corresponds to female homicides. Gender-violence victims (femicides) represent the 80% of female homicides (N=1,711). My analysis also uses the domestic violence survey of 2011 and 2019 to identify the evolution of women empowerment at the municipality level.

To test the existence of a retaliation effect after the 2014 reform of the penal code, I analyze the association between the increase on the female homicides rates at the municipality level and the changes in women empowerment. First, I examine whether or not the female homicides increased more in those municipalities that enforced the application of the new penalty type *femicide*, than in those that did not apply it, after the approval of the new penal code. Similarly, I analyze whether or not female homicide rates increased more in municipalities that present a growth in the level of women empowerment, than those presenting a decrease in the level of women empowerment.

Main results. The results of this investigation show that the municipalities that did not enforce the new *femicide* penalty type experienced a decrease of female homicide rates from 4.3 to 2.81 victims per 100 thousand inhabitants, from the period 2010-13 to the period 2014-17. By contrast, the municipalities that enforced the *femicide* classification had an increase of the female homicide rate from 2.18 to 2.85 victims per 100 thousand inhabitants, between the same two periods. When considering the evolution of women empowerment, I observe that those municipalities that exhibited an increase in the level of women empowerment, the female homicides rates increased from 1.89 to 2.03, from the period 2010-13 to the period 2014-17. By contrast, the municipalities that experienced a reduction in the level of women empowerment show a decrease in the number of female homicides from 2.8 to 1.35 victims per 100 thousand inhabitants, between the same two periods. My research also examines whether the reform of the penal code of 2014 generated a retaliation effect that increased the number of femicides. I find that enforcement of femicide classification is associated with a 0.28 SD increase in the female homicide rate, in municipalities with an increase of women empowerment.

Contribution and policy implications. The results of this chapter suggest the possibility of a retaliation effect in Ecuador after the approval of the new penal code in 2014. Moreover, the findings of this paper suggest that enforcing the *femicide* penalty, accompanied with women empowerment, has been associated with a raise in the female homicides and the gender-violence rates, due to the male backlash effect. The result is in line with the findings of other papers that analyze the effects of interventions targeted to mitigate domestic and gender-violence in developed countries (Angelucci, 2008; Banerjee, La Ferrara and Orozco, 2019), or that examine the effects of legal reforms to reduce domestic violence (Zelcer, 2014; Leisenring, 2012). The results of this analysis show that the strategy to avoid future gender-violence victims with the penalization of female homicides might have temporarily created a retaliation effect, in Ecuador.

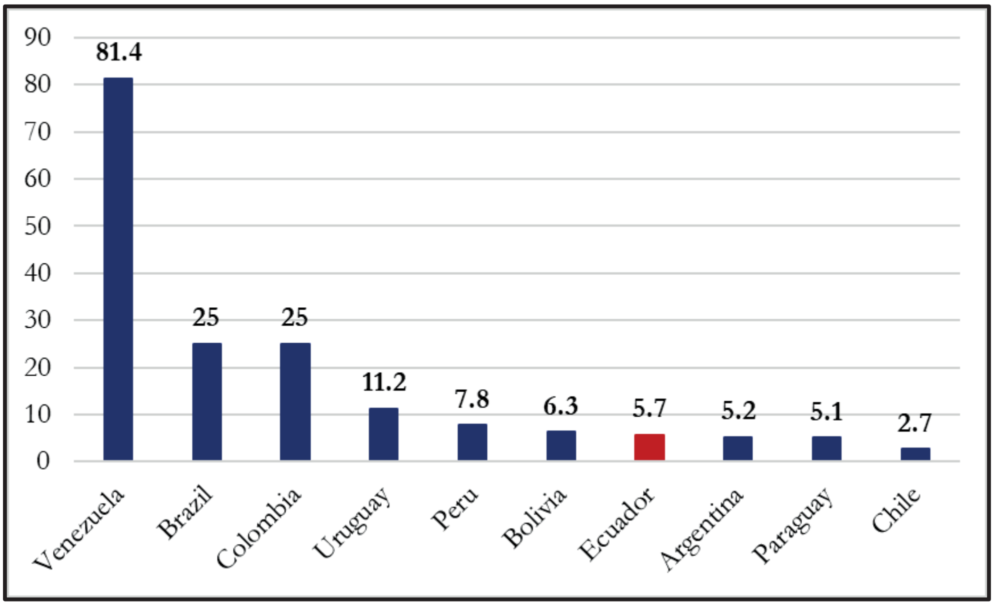
The findings show the necessity to complement legislative reforms with educational campaigns that mitigate the backlash effects of women empowerment. Future research should examine factors that can be used to mitigate and avoid new cases of gender-violence and female homicides, such as the number of criminal complaints against the partner, or visits to the social services. This information can be used to redirect and design new interventions in some communities to balance social norms, to increase the education levels and to favor women empowerment. It can also be used to improve the support to females at risk of being victims of violent and traumatic experiences.

Chapter 4. The third research objective of my thesis is to analyze whether or not the presence of violence and homicides in a community can affect the health conditions of its members. The title of the fourth chapter of my thesis is "*The aftermath of crime: indirect exposure to homicides, maternal stress, and newborns' health*", and it examines the effects of indirect exposure to homicides on newborns health outcomes, in Ecuador. Violent crimes are a severe problem in Ecuador, and they vastly cause insecurity, fear, and stress on the population and especially on the pregnant mothers. This chapter provides new evidence that violent crimes can generate maternal stress and negatively affect newborns' health.

Motivation. The economic literature has spent many efforts to understand the consequences of direct assaults, and other source of stress that directly affects pregnant women. Having a complete understanding of the consequences on the indirect victims of violence is necessary to orientate public policy to avoid persistent stress of indirectly exposed mothers.

Violence is a significant problem in Ecuador, although the number of homicides has dropped importantly in recent years. While in 2008 the number of homicides was of almost 18 cases per 100 thousand inhabitants, in 2020 the number decreased to 6.1 cases per 100 inhabitants. Figure 1.3 illustrates that Ecuador is one of the Latin American countries with lowest homicide rate in 2018, according to the InSight Crime Organization statistics. In the period 2010 to 2020, almost the 80% of all Ecuadorian municipalities have reported at least 1 homicide. However, violent crime is concentrated in large cities, and specially in Quito, Manta and Guayaquil. In this period there were nearly 14,000 homicides in the country. The most common cases were related to: (1) community violence (48%). These homicides refer to homicides that result from emotional violence, and fights and disputes between the members of the community; (2) quotidian crime (38%), which is the result of criminal activities, such as robberies; and (3) domestic violence (13%), which usually refers to femicides (Ministerio de Gobierno, 2019; INEC, 2020; Pontón et al., 2020).

Figure 1.3- Homicide rate per 100,000 inhabitants in South America, in 2018



Source: Authors' elaboration. Data retrieved from InSightcrime Organization.

Despite the efforts to mitigate violence and crime, very few policies have been designed to mitigate consequences on the direct and indirect victims. One exception are the norms and protocols released by the Ministry of Health in the year 2008 to assist women and children that were victims of sexual, domestic and gender-based violence, and to those who witnessed violent crimes (Ministerio de Salud, 2008). However, there is no such measure that can mitigate efficiently psychological stress from violent crimes.

Background. Several economists and social scientists have dedicated their research to understand the negative impact of different socio-economic shocks on newborn health. This chapter contributes to this literature analyzing the impact of maternal stress produced by the indirect exposure to homicides on newborns health outcomes. Maternal stress can be caused by several shocking events such as the loss of a family member during pregnancy (Persson, Rossin-Slater, 2018), terrorist attacks (Quintana-Domeque, Ródenas-Serrano, 2017), mafia activities (Torche, Villarreal, 2014), and exposure to weather shocks such as hurricanes (Currie, Rossin-Slater, 2013). These and similar studies have shown that conflict events and terrorism cause maternal stress and exacerbate gestation length and birth weight, especially when it occurs in the first trimester of pregnancy (Camacho, 2008; Torche, 2011; Vinkelsteijn et al., 2004; Ahern et al., 2018; Hoffman et al., 2016).

My paper closely follows the studies analyzing the effects of assaults and street violence on newborn health (Koppensteiner and Manacorda, 2016; Currie, Muller-Smith, and Rossin-Slater, 2020). The contribution in regard with these studies is that I consider the effect of indirect exposure to homicides in the mother's surroundings rather than the effects of direct assaults. Moreover, I am able to compute an individual exposure measure, which allows to identify whether or not the newborn was exposed to a homicide in the mothers' surrounding area. Furthermore, the main analysis controls for past exposure to violent crimes and shows that it attenuates maternal stress during pregnancy. To my knowledge, the attenuation effect due to past exposure to violent crimes has not been studied in the context of a developing economy.

Data and empirical strategy. To test the effects of maternal stress of violent crimes on newborn health, this chapter combines the information of the National Register of Live Births for the period 2010 to 2018, with the National Registry of Violent Deaths from 2010 to 2018. The former contains information for nearly 350,000 newborns per year across the whole country for the period 2010 to 2018. Information on newborns including the mother's address during pregnancy is only available for the period 2015 to 2017 and, after a filtering process to eliminate imprecise locations and inaccurate addresses, it contains data for around 495,000 newborns for this period. On the other hand, the National Registry of Violent Deaths contains information of each homicide's geographical coordinates of occurrence, for almost 14,000 homicides across the whole country for the period 2010 to 2018. The data quality enables to compute an individual level measurement of exposure to violent crimes. Particularly, I bring together the mothers and the homicides' location information to compute an exposure variable and a variable that reflects mothers past exposition to homicides.

A concern to this study is that households living in or close to areas with active criminal activity might have different characteristics than those living at a larger distance from them, and for this reason, it is difficult to disentangle the causal impact of crime from unobservable factors that systematically affect newborn health. To solve for endogeneity on violent crime exposure, I have used three different approaches to analyze the effect of indirect exposure to homicides on newborns' health. First, I develop a fixed effects model that compares the birth weight of newborns that during the pregnancy period were indirect exposed to different homicides rates in their municipalities during the period 2010-2018. The second identification strategy consists of a DID estimation that analyzes the difference between being exposed to a homicide during pregnancy or not, relative to the analogous difference of being exposed within the 9 months following newborns' birth. To do so, I consider a sample of newborns born in the period 2015-2017, for which information on the mother's residential addresses is available. This analysis also considers whether the mothers' stress generated by the indirect exposition to a homicide during pregnancy can be attenuated when the mothers were previously exposed to other crimes. The third identification strategy follows a maternal fixed-effects estimation considering a sample of the newborns born to the same mother but that had different indirect exposition to homicides during gestation. As in the previous strategy, this estimation examines the effect of being exposed or not during pregnancy, relative to the siblings exposed or not within the 9 months following the due date.

Main results. The main findings of this paper can be summarized as follows. The first identification strategy compares the birth weight of newborns exposed to different homicide rates in their municipalities during gestation, and it reveals that newborns exposed to more violence have negative effects on birth weight. The results show a birth weight deficit of between 4.5 to 15 grams. Interestingly, the birth weight deficit is higher in municipalities that have a low number of homicides per year. This result suggests that maternal stress may be related with the occurrence of unexpected crimes in the mothers' neighborhood.

The second estimation suggests that the effects of exposure to homicides are statistically significant when exposure occurs during first trimester of gestation. Moreover, the effect becomes larger when I restrict the analysis to municipalities with very few homicides events. The results drawn from this model suggest that exposure to homicides during the first gestation stage generates a birth weight deficit of between 20 to 31 grams, compared to newborns whose mothers are exposed to crime post-pregnancy. Moreover, the results from this model show that mothers may be less emotionally impacted by homicides occurring during the pregnancy when they live in a neighborhood with frequent episodes of violence.

The maternal fixed-effects estimation shows that the exposure to homicides is statistically significant when exposure occurs during the last gestation stage. The results drawn from this model suggest that exposure to homicides during the third gestation stage generates a birth weight deficit of between 111 to 200 grams, compared to siblings exposed to crime post-pregnancy. I also find that the exposure to homicides leads to a reduction in the gestational length and to a deficit the 1st minute Apgar score, when the siblings of the same sex were exposed to homicides in their last trimester of gestation.

Contribution and policy implications. This paper contributes to a growing body of economic, psychological, and medical literature that examines the effects of prenatal conditions and maternal stress on health at birth. Firstly, I provide new evidence of the causal relationship between the in-utero exposure of newborns to homicides at each stage of gestation and its impact on newborn health outcomes. Secondly, I propose precise measurement of newborns' indirect exposure to crime, which captures the mothers' distance from the homicides during gestation and their exposure to other violent crimes in the past. Thirdly, each of the three identification strategies to test for the impact of violence on health at birth draws consistent results of the negative impact of exposure to homicides on newborns health outcomes.

My findings in this research are in accordance with those found in other analyses of the effects of landmine explosions in Colombia (Camacho, 2008), and also of large terrorist attacks in Spain (Quintana-Domeque, Ródenas-Serrano, 2017). The former finds that birth weight is reduced by 9 grams when one landmine explosion occurs during early pregnancy. The later computes that the effect of being exposed to terrorism results in a birth weight reduction of 42.12 grams.

Overall, the findings in this chapter highlight the importance of establishing social and health policies targeted at addressing the stress and insecurity of the affected individuals. The government's efforts should aim to enhance community safety, counteract violent crimes, and offer prenatal controls and psychological support to safeguard the mental health of mothers exposed to violence during pregnancy. Moreover, the results suggest for policy interventions to support direct victims of violence parallelly with other policies to reduce environmental stress in all women and newborns living in the areas affected by violence and crime.

The chapters 2 to 4 of this thesis present each of the three academic papers. The fifth (and last) chapter describes the featured results and provides arguments and discussion for public policy implications of the results. I present final remarks and proposal for future research.

2 Chapter 2 – The hidden cost of bananas: pesticide effects on newborns' health

2.1 Introduction

The increasing demand for agricultural products, combined with land restrictions and changing weather conditions, has impelled farmers across the world to adopt extensive use of agrochemicals to increase productivity and reduce crop loss (Cassou, 2018). This use of chemicals has severe negative effects on populations living close to the farms or working on them. It is estimated that pesticides cause 200,000 acute poisoning deaths each year, most of these in developing countries, and have catastrophic impacts on health in communities living near agricultural land (Svensson et al., 2013; UNHR, 2017). In recent decades, national governments and international institutions have adopted different initiatives to limit the use of pesticides and to protect their populations (UNEP, 2014; Watts, 2013; USEPA, 1996; CPR, 2015; Martinez-Alier et al., 2016). Yet, there are few studies using information for large-scale communities and demonstrating a causal effect of pesticides on the population's health that be used to orient public policies. This paper contributes to understand the health implications of pesticides by examining the impact of aerial fumigation of the banana plantations in Ecuador.

There is a growing body of literature addressing the consequences of air pollution on children's health. The economic research has shown that birth weight, gestational length, and in utero survival are all affected by industrial activity (Hansman et al., 2019), environmental regulations (Greenstone and Hanna, 2014; Tanaka, 2015), major forest fires (Frankenberg, McKee, and Thomas, 2005; Tan-Soo and Pattanayak, 2019), agricultural fires (Rangel and Vogl, 2019) and indoor pollution (Hanna, Duflo, and Greenstone, 2016; Barron and Torero, 2017). Several papers have also raised an alert about the persistent effects of air pollution on physical development and cognitive ability (Currie et al., 2014; Rosalies-Rueda and Triyana, 2018; Molina, 2020).[3] In spite of this, there are few studies analyzing the effects of the intensive use of pesticides in agriculture (some exceptions are

[3] More generally, the research shows how health at birth can affect health status in adulthood (Barker, 1995) and socio-economic outcomes such as school attainment, high school graduation or earnings during adulthood (Black et al., 2007; Currie and Vogl, 2013; Bharadwaj et al., 2013; Almond and Currie, 2011; Almond et al., 2005).

Bustos et al., 2016; Camacho and Mejia, 2017; Larsen et al., 2017; Dias et al., 2019; Maertens, 2019). Farms around the world use pesticides to fight against fungus, pests, and crop disease, but in order to regulate these activities it is important to understand the causal effect of exposure to pesticides on health outcomes for workers and the neighboring population.

Ecuador provides an excellent case to analyze the effects of pesticide use in agriculture. Ecuador is the fifth largest producer and the largest exporter of bananas in the world. In the last few decades, national producers have dedicated significant efforts to increasing their efficiency and have incorporated the use of agrochemicals on a massive scale at different stages of the production process (Maldonado and Martínez, 2007; Harari, 2009; FAO, 2016). In the early 1970s, banana producers started to use aerial fumigations to treat the disease known as *Sigatoka Negra*, the main fungal disease affecting banana fruit plants. Despite the effectiveness of fumigations in stopping the spread of this fungus, there are important concerns about its environmental and health implications (Naranjo-Marquez, 2017; Defensoría del Pueblo, 2019). Children and adult populations who live, attend school or work near banana fields are exposed to high levels of pesticides and this makes them vulnerable to different types of diseases. Public interest in this problem has prompted the regulation of aerial fumigations.[4] Specifically, in 2012, a new law was passed that sets a protective distance between fumigated areas and neighboring households. Despite this, the lack of enforcement capacity of the responsible authorities and the defiant climate conditions might reduce the effectiveness of this measure (UNHR, 2017).

The objective of this study is to examine the effects of pesticide fumigation of banana plantations on newborns' health in Ecuador. Analyzing the causal effects of agricultural pesticides on nearby residents' health entails two important difficulties. First, households' addresses are usually not available for confidentiality reasons and, as a result, location is usually approximated using the centroid of the reported neighborhood or municipality (Bustos et al., 2016; Camacho and Mejia, 2017; Dias et al., 2019; Maertens, 2019; Rangel and Vogl, 2019). Moreover, the lack of precise information on the perimeter of the plantations generates inaccuracies on exposure measurement. Our paper overcomes these problems with the creation of an exposure variable that is based on the geolocation of the mothers during pregnancy and on the perimeter of the fumigated plantation. For each mother, we create 25–meter-radius buffers from their residential address up to 2.5 kilometers, which compute the number of fumigated square meters of banana plantations.

[4] See for example the following media reports and interviews: (1) https://www.americaeconomia.com/negocios-industrias/defensoria-de-ecuador-advierte-riesgo-de-quimicos-en-bananeras; (2) https://www.planv.com.ec/ investigacion/investigacion/vivir-y-morir-del-banano

We use this information to construct an exposure measure that weights the resulting 100 buffers using a decaying kernel function.[5] This approach offers a precise measurement of newborns' in-utero exposure to fumigated plantations that allows us to estimate the effects of pesticides on birth outcomes (weight at birth, Apgar score at first minute, and gestational length).

An additional challenge for analysis the effects of pesticides on newborns' health is the possibility that households living close to the plantations have different characteristics than those living at a larger distance from them, which makes difficult to disentangle the causal impact of pesticides from unobservable factors that affect newborns' health (Chay and Greenstone, 2003; Greenstone and Hanna, 2014; Cesur, Tekin and Ulker, 2017; Rangel and Vogl, 2019). We overcome potential endogeneity of exposition to pesticides by implementing three different empirical designs. First, we exploit the seasonal changes in the intensity of fumigations across provinces. Banana plantations are fumigated over the whole year, but fumigations are more intense during the rainy season, which is when the *Sigatoka Negra* fungus propagates more easily. We use seasonal fumigation patterns across provinces to estimate a difference-in-differences (DID) estimation that compares the difference between newborns born to mothers living in exposed areas in intense and non-intense fumigations seasons, relative to the difference between newborns born to mothers living in non-exposed areas in the same two seasons. Second, we estimate a DID model that compares the difference between newborns exposed and not exposed to fumigated banana plantations, relative to the difference between newborns exposed and not exposed to any other crops. This analysis is based on the fact that other crops (rice, cocoa, and corn) produced in Ecuador are fumigated much less intensively than banana plantations and on the assumption that in each municipality the population living close to banana plantations and living close to the other crops are not statistically different. Third, and finally, we use a sub-sample of mothers that had more than one child during the period we study to estimate a model with maternal fixed effects. During this period, a relevant percentage of mothers moved to a different address, which allows us to analyze the difference in birth weight between siblings exposed and not exposed to pesticides during gestation.

Our study draws on a public data set obtained from the National Register of Live Births (*Registro estadístico de nacidos vivos*) for the period 2015-2017, which contains information for nearly 270 thousand newborns and from which we obtained the mothers' residence

[5] The effects of pesticides (and of other types of air pollutants) vanish importantly for distances longer than 100-250 meters (Currie et al., 2009; Currie et al., 2015; Deziel et al., 2017; Dereumeaux et al. 2020; Gibbs et al., 2017). We calculate the buffers for a distance of up to 2.5 kilometers from the mothers' residences to be able to perform several robustness checks.

addresses during pregnancy. Almost 51 thousand of these mothers resided within 2.5 kilometers of the banana plantations, which is the distance we use to construct the exposure buffers. This data set includes information on several observable characteristics of children and mothers. We complement this data set with information on Ecuador's banana plantations from the 2013 agricultural census and the 2014 register of aerial fumigations. The former contains information on the perimeter of each plantation and the use of aerial or manual fumigations, and the latter contains geocoded data on the application of pesticides (i.e., quantity, toxicity, date of application). We combine the information on the mothers' locations, the perimeters of the plantations and the use of pesticides to calculate the exposure measure for each newborn.

The results of our analysis confirm the hypothesis that pesticides have a relevant impact on newborns' birth weight. Our baseline analysis of the exposure measure shows that most of the effect of pesticides occurs within the first 100-150 meters from the plantation and that this impact quickly vanishes at longer distances. We use this result to create the group of treated and control newborns that are used in the causal analysis. Our first identification design shows that pesticides have a relevant impact on newborns health when the first and the second trimesters of gestation coincides with the season of intense fumigations. Newborns exposed to intense fumigations during this gestational period have an average birth weight that is between 38 and 89 grams lower than those not exposed. This effect is larger for newborn girls and for those born to low-educated mothers. These results should be considered as a lower bound for the effect of pesticides, since all newborns located close to the plantations can be affected by fumigations. Our second model compares the mothers' exposure to banana plantations with an analogous exposure to other crop plantations (rice, corn, cocoa). In this case, we obtain that being exposed to banana plantations reduces birth weight by approximately 29 to 76 grams. Finally, the third identification strategy uses a maternal fixed effects model to compare siblings exposed and non-exposed to pesticides. Here, we find that newborn girls, exposed to pesticides in utero, have an average birth weight 250 to 346 grams lower than that of non-exposed siblings.

The estimated average effect that we obtain for the exposure to pesticides in Ecuador is greater than the 30 grams found by Bozzoli and Quintana-Domeque (2014) for the effects of the collapse of the economy in Argentina in 2000-05, and also greater than the 23 grams found by Rangel and Vogl (2019) for the effect of sugar cane harvesting in Brazil. However, it is close to the 200-grams effect found for mothers that smoke (Kramer, 1987; Lindbohm et al., 2002) and to the 30-200 grams found in recent medical and environmental studies on the use of pesticides in agriculture (Rauch et al. 2012; Gemmill et al., 2013; Tago et al., 2014; Larsen et al., 2017; Mostafalou and Abdollahi, 2017).

Our research contributes to the literature analyzing external factors that affect fetal health during gestation.[6] Previous works have shown that economic shocks during gestation affect fetal health, especially in the third trimester of pregnancy. This effect has been identified for the Dutch famine (Stein and Lumey, 2000), the food stamp program in the United States (Almond, Hoynes and Schanzenbach, 2011) and the economic crisis in Argentina in the period 2000-2005 (Bozzoli and Quintana-Domeque, 2014). Other papers have evidenced that maternal stress due to exposure to different types of violence affects birth weight, especially when it occurs in the first trimester of pregnancy (Camacho, 2008; Torche, 2011; Koppensteiner and Manacorda, 2016; Currie et al., 2020). Additional research has documented that fetal health can be negatively affected by in utero exposure to temperature level variations (Andalón et al., 2014; Rocha and Soares, 2015; Deschênes et al., 2017), rainfall shocks (Pereda et al., 2014; Rabassa et al., 2014) and natural disasters (Simeonova, 2011; Currie and Rossin-Slater, 2013).

Our paper is more closely aligned to the body of evidence documenting the effects of air pollution on newborns' health outcomes (Currie, Neidell and Schmieder, 2009; Chen, Ebenstein, Greenstone and Li, 2013), children (Hyland and Laribi, 2017; Ding and Bao, 2014) and adults (Lai, 2017).[7] Among these, we contribute to the literature studying the effects of pollution from agricultural activities on fetal and child health (Hyland and Laribi, 2017; Lai, 2017). The literature has used different approaches to identify the causal effect of pollution on the population's health. Rangel and Vogl (2019) estimate the effect of smoke from agricultural fires in Brazil on health at birth. Exploiting daily changes in the location of fires and wind direction for identification, they find that late-stage pregnancy exposure to smoke from upwind fires decreases birth weight by 23 grams, gestational length, and in utero survival. Dias et al. (2019) examine the impact of glyphosate use in soybean-producing areas of Brazil on birth outcomes in the surrounding populations. They find that locations receiving water from areas that expanded the use of glyphosate

[6] "External factors" such as environmental and meteorological conditions are not controlled by pregnant women and can affect fetal health. Mothers' respiratory ingestion of particles can penetrate the placental barrier, through the blood system, and reach the fetus. "Internal factors" are related to a mother's genetics, health, nutrition, behavior and living conditions.

[7] Laboratory and case-control medical research studies have shown the biological mechanisms that intervene in in utero exposure to pesticides. They show the relevance for health outcomes at birth of exposure to pesticides in the last trimester of pregnancy (Laborde et al., 2015). Some case-control studies have shown that the number of pesticides in cord blood is inversely related to birth weight (Wang et al., 2012; Wickerham et al., 2012; Konishi et al., 2009; Vizcaino et al., 2014). Laboratory studies also point out the negative health implications of fumigation compounds, which can cause skin and brain diseases, fetal malformation and several more diseases in children and adult individuals (Byrns and Fuller, 2011; Bain, 2010; Bradman et al., 2003; EJF, 2003; WHO, 2005; OPS/OMS, 2007; Ling et al., 2018).

in the 2000s experienced significant deterioration in infant mortality and in the frequency of low birth weights. Maertens (2019) estimates the health impact of a pesticide called atrazine, using as instrument the expansion in corn production driven by enactment of the Renewable Fuel Standard (RFS) in 2005 in the US. His strategy relies on the plausibly exogenous geographic variation in potential for corn expansion after the introduction of the RFS and on the seasonal variation in corn pesticide applications during the year. Results show that the persistent demand shock that followed the introduction of the RFS increased the risks of abdominal wall defects, fetuses being small for gestational age, and perinatal death. Jones (2020) investigates the relationship between infant health and agricultural pesticide use for the period 2005-2015 in the United States. His identification strategy is based on the fact that initial spotted wing drosophila (a fruit fly) at the county level is associated with the use of pesticides. This paper finds that the increase in insecticide and fungicide use is associated with a n increased instances of infant prematurity and low birth weight.

This research is also related to the medical and environmental studies that have used geographical buffers to examine the effects of pesticides on health at birth. These studies compute the pesticide exposure by summing the pesticides applied in the area close to the mother's residence during pregnancy, although they do not usually have precise information about the perimeter of the plantations and for this reason, they use relatively large buffers. Gemmill et al. (2013) analyze whether residential proximity to methyl bromide applications is associated with fetal growth and gestational length in a cohort of pregnant women living in an agricultural community in the Salinas Valley (California, USA) in the period 1999-2000. Their findings suggest that an increase in methyl bromide use in the second trimester of gestation was associated with decreases in birth weight of 113 grams, birth length and head circumference, for residents close to the pollution source. Larsen et al. (2017) examine the use of pesticides in the agricultural land of San Joaquin Valley (California, USA) for the period 1997-2011. They find that agricultural pesticide exposure increases adverse birth outcomes, but only among the population exposed to very high quantities of pesticides. They find a statistically significant decrease in birth weight of about 13-30 grams following cumulative pesticide exposure and pesticide exposure in the first trimester for individuals in the high exposure group.

The rest of the paper is organized as follows. Section 2 describes the banana plantations in Ecuador, the use of pesticides and their potential health impact. Section 3 describes the data and the merging strategy. Section 4 describes the empirical strategies. Section 5 presents the results. Finally, Section 6 concludes and discusses public policy implications.

2.2 Background

2.2.1 Banana plantations in Ecuador

Banana production is one of the main economic activities in Ecuador. In 2016, banana plantations covered more than 186,000 hectares and produced more than 6.5 million tons of bananas, which represents 6% of the world's total production. Banana exportation accounts for 2% of total Ecuadorian GDP and represents approximately 35% of the agricultural sector's share of GDP (BCE, 2017). The banana plantations are mostly concentrated in the coastal region of the country, which has adequate weather conditions and soil nutrients for raising this crop. Most of the country's population is concentrated in this region.

The strategic relevance of this crop has led the government to control its production. In 2010, the government banned the expansion of banana plantations across the whole country, regardless of their size, structure, and variety of fruit.[8] This was justified by the large number of plantations (registered and unregistered) with very low productivity rates. Moreover, in 2012, the Ministry of Agriculture created the Banana Unit (*Unibanano*), which acts as a registry for plantations, regulates their activities and promotes their efficiency. *Unibanano* assists producers in the exportation of their fruit and the acquisition of inputs, guarantees a minimum reserve price according to the quality of the fruit, and promotes the establishment of specific labor regulations for the sector. Because of these interventions, the price received by banana producers has been very stable in the period we consider (Figure 2.A1 in Appendix A).

2.2.2 Plantations and aerial fumigation

The phenological stages of banana plantations are seeding, growth, blossoming and harvesting. After the seedtime, farms control the development of banana trees and apply pesticides to preserve the health of the plantations and quality of the bananas. Later, during the blossoming and harvest, they apply agrochemicals to maintain the fertility of the soil and preserve the young seedlings, but fumigations are less intense. Pesticides are applied

[8] Although there are several types of bananas, all of them receive the same fumigation treatment. The most common variety, representing more than 90% of the production and exportation is called Cavendish.

manually with pumps or from airplanes, which are frequently contracted by several farmers collectively.[9] Aerial fumigations were first adopted in the early 1970s to treat a fungal disease known as *Sigatoka Negra* (*Mycosphaerella Fijiensis*). This fungus generates a leaf-spot disease that causes progressive destruction of the foliage and the photosynthetic process. The infected plant reaches the flowering stage with a reduced number of leaves, accelerating the maturation process and causing the fruits to shrink or die. The main factors contributing to the spread of *Sigatoka Negra* fungus are high temperature, high rainfall, and light. In the coastal region of Ecuador there are small variations in temperature and luminosity from one season to the other, but precipitation is concentrated in the winter period (usually from January to May). The rain and humidity of the winter season favor the spread of *Sigatoka Negra* across the banana trees (Jesus Júnior et al., 2008; Khan et al., 2015) and for this reason producers intensify fumigations in this period.[10] As we explain later, the seasonal use of fumigations is the base of one of the identification strategies that we use to analyze the causal effect of the intensive use of pesticides on newborns' health.

The Ecuadorian government has introduced several measures that stipulate a minimum distance from *aerial fumigation* sites to households and public spaces. In October 2012, a law established a protection distance of 200 meters from households, schools, health centers and highways and a requirement to construct natural barriers to protect public spaces. *Manual fumigations* were banned within 50 meters of these areas. In February 2015, a new regulation established a security distance of 60 meters where there were no living tree barriers, and 30 meters with living tree barriers, from riversides and water infrastructure not dedicated to human consumption. These distance regulations have relevant consequences for banana producers who must apply pesticides manually in the plantations close to households, which is more expensive. The Ministry of Agriculture has also promoted the use of greener actions, such as growing soy and maize, to complement the production of traditional crops such as banana, cocoa, and palm oil. These measures are considered to increase the productivity of plantations and reduce the use of pesticides.

[9] The use of pesticides is one of the main economic costs for producers. Around 60% of their annual budget is spent on plantations maintenance, control of pests and fungus diseases (MAGAP, 2013).
[10] Banana plantations could also pollute water sources, as recently evidenced by Dias et al. (2019). In Ecuador, there are specific regulations of water system in plantations to avoid water draining and pollution.

2.2.3 Pesticides and health

Several medical and environmental studies have shown negative health effects for households close to agricultural land affected by pesticides. According to the World Health Organization (WHO), absorption of pesticides occurs by inhalation, accidental ingestion and by penetration through the skin. Pesticides are absorbed more quickly if the formulation is liquid, oily or if the skin is hot or bears injuries. The type of exposure that presents most risk for human health is the inhalation of dust, airborne droplets, vapors, or gas, that enable smaller particles to reach the alveoli, and to enter the bloodstream directly.

The literature has found higher pesticide concentrations in blood and urine tests, and in both outdoor and indoor surface deposition of chlorpyrifos, in residences located within 60 meters, 100 meters and up to 250 meters of agricultural fields (Coronado et al., 2011; van Wendel de Joode et al., 2012; Deziel et al., 2017; Gibbs et al., 2017; Dereumeaux et al., 2020). Benner et al. (2014) examine glyphosate aerial drift distances and find the presence of high concentrations of glyphosate in areas located within the first 226 meters from the pollution source[11]. Whyatt et al. (2004) and Rauh et al. (2012) have shown a direct correlation between chlorpyrifos exposure and higher risk of intrauterine growth restriction, low birth weight and small cranial circumference at birth, when exposure happens at short distances from the plantations. More recently, Friedman et al. (2020) found that children in households located within 100 meters of floricultural lands in an Ecuadorian municipality have lower average neurobehavioral performance than those living in locations further away.

Other papers have exploited seasonal variation in the application of pesticides by comparing seasonally exposed and non-exposed households, finding that seasonally exposed households have higher concentrations of pesticide metabolites in urine samples and a decrease in nervous system functioning (Bradman et al., 2011; Cecchi et al., 2012; Galea et al., 2015; Quintana et al., 2017). [12]

The medical literature has shown that exposure to pesticides during gestation can cause intrauterine growth restriction, weight problems and birth defects. In the embryonic stage,

[11] The authors also find pesticide particles at beyond 2.5 kilometers. The drift distance mainly depends on meteorological factors, droplet size and the pressurized airflow from the nozzles. For common cases, in which the droplet size is 150 ums (dense substance), pesticides will drift less than 226 meters.

[12] Some case studies have found high levels of dermatological, lung, and functional system incidences on the population living near banana plantations during the winter season (Laborde et al., 2015; Harari, 2009).

pesticides are especially damaging, as this is a critical period for prenatal development and birth weight. Later, during the fetal stage, the environment provided by the mother affects the baby's size and health, rather than the formation of organs and limbs (Bernstein and Nash, 2008). During the second and third trimester of gestation, growth is important for these structures and organs, and the fetus begins to gain weight steadily. In this period, harmful exposure to pesticides can lead to functional defects like learning problems (Bleyl, 2010; Carlson, 2008; Cochard, 2012; Moore, 2013).

2.3 Data and merging strategy

The paper combines different administrative data sets: the Ecuadorian register of newborns for the period 2015-17; the 2013 census of banana plantations; the 2016 satellite map of rice, cocoa, and corn, and the 2014 register of aerial fumigations.

Newborns register

The national register of live births from the National Institute for Statistics and Census (INEC) is a data set containing information for all newborns in Ecuador. We use the information from the years 2015 to 2017, which is the period for which the mother's address during pregnancy is available. The register comprises information for more than 300 thousand newborns per year across the whole country, although our analysis focuses on the provinces with banana plantations.

The data set includes the birth weight measured in grams, the gestation length in weeks and the Apgar score at the first minute, which are the outcome variables used in the paper. In addition, it has information about birth conditions (number of prenatal controls, type of delivery, number of previous births, multiple births), newborn characteristics (sex, birth order) and mother characteristics (education level, ethnicity, marital status, C-section) that according to the economic literature are relevant factors for newborn health outcomes (Bharadwaj, Loken and Neilson, 2013; Almond and Currie, 2011; Almond, Chay and Lee, 2005). Following Bozzoli and Quintana-Domeque (2014), we focus on mothers aged 15 to 49 and we exclude newborns whose weight was either under 500 grams or above 9,000 grams. Following Larsen et al. (2017), we also exclude very premature births with gestation of less than 26 weeks and those births at later than 50 weeks.[13]

Banana plantations census

Information about the banana plantations comes from the 2013 *Catastro Bananero,* from the *Ministerio de Agricultura, Ganadería Acuacultura y Pesca* (MAGAP). Banana plantations are present in around 140 municipalities that belong to 5 provinces of the coastal region of Ecuador.

This census contains the information on the plantations' locations and perimeters that we use to construct our exposure variable. It also contains other relevant information about the plantations, such as the fumigation method (aerial or manual fumigation) and the surface. In our analysis, we assume that the plantations' perimeter has remained stable since 2013, which is when the government restricted the amount of land that can be dedicated to banana plantations.[14]

Approximately 85% of the total plantations in our study employ aerial fumigation, although aerial fumigation is ubiquitous for large plantations. Indeed, while only 31% of the small plantations (less than 5 hectares) use aerial fumigation, the percentage rises to 97% for large plantations (more than 30 hectares). At this point, it is important to note that large plantations usually surround smaller ones, and that in many cases aerial fumigation is contracted collectively.

Figure 2.1 presents the geographic distribution of the banana plantations in Ecuador and shows how mothers' residences are usually surrounded by several plantations at different distances. In the lower right image, the yellow areas are the banana plantations that apply aerial fumigation, and the red dots are the mothers' residences during pregnancy.

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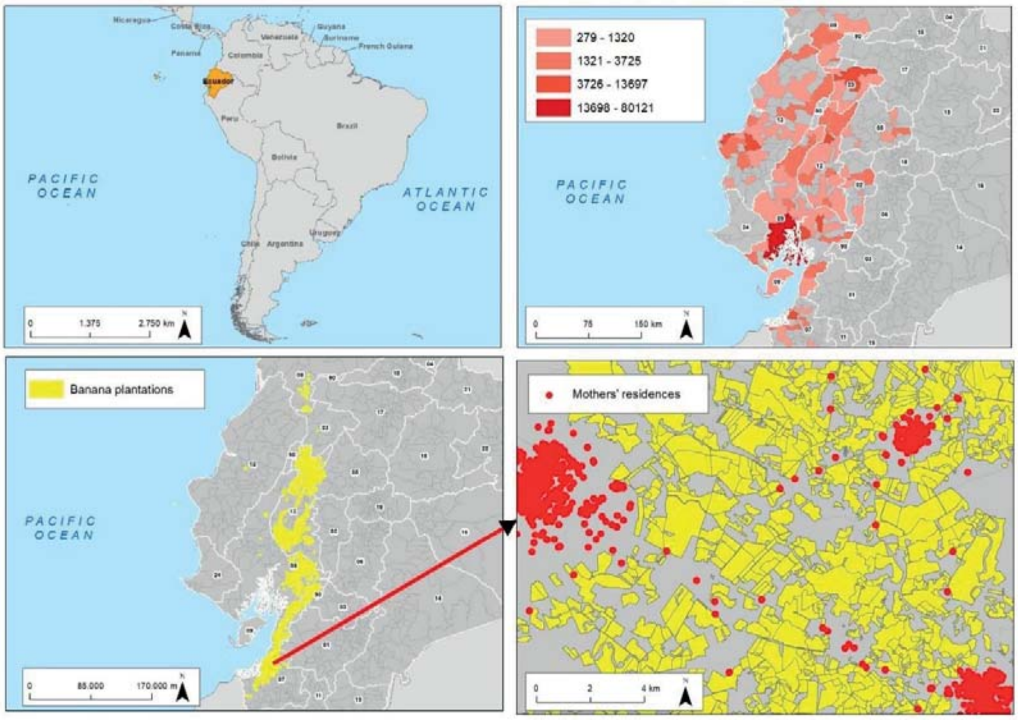
[13] We excluded 4,500 observations of births from mothers aged under 15 and over 49 years old, respectively. No observations are excluded from the birth weight criteria. 613 observations are excluded from gestation week criteria. Our results are consistent and robust to the reported estimates when including these observations into the analysis.

[14] According to the Ministry of Agriculture, the extension of banana plantations has not undergone relevant changes since 2013. In 2004, the government forbid the use of more land to grow bananas (*Ley para Estimular y Controlar la Producción y Comercialización del Banano, Plátano (Barraganete) y otras musáceas afines destinadas a la exportación*, coded in the *Registro Oficial -S315 del 16 de Abril del 2004*). In 2010, new banana farms were allowed, subject to the authorization of the Ministry of Agriculture (*Suplemento - Registro Oficial Nº 351 - 29 de Diciembre del 2010*). In addition to these regulations, between 2012 and 2013, the Ministry of Agriculture created the census of plantations to control production.

Figure 2.1 - Mother's locations and banana plantations in Ecuador (2015-2017)



Note: The upper left image shows the location of Ecuador in South America. The upper right image presents the geographic distribution of newborns across provinces with banana plantations. The lower left image shows the location of banana plantations in Ecuador in yellow color. The lower right imagine is an example to illustrate that mothers' residences (red dots) are usually surrounded by several plantations (yellow areas) at different distances.
Source: INEC – MAGAP

Aerial fumigation register

Information on the type and quantity of pesticides applied in banana plantations comes from the 2014 register of aerial fumigation activity, gathered by the *Dirección General de Aviación Civil (GDAC)*, the institution responsible for controlling air activity in Ecuador. The register was created by the Project for Environmental Reparation of the Environment Ministry in 2014 and has not been updated since. It contains information about the dates and coordinates of aerial fumigations, the chemical compounds, toxicity degrees and quantities in gallons of agrochemicals.

This register indicates that nearly 3.5 million gallons of agrochemicals was aerially sprayed in banana plantations in 2014, of which 90% are classified as moderate to high toxicity pesticides.[15] Pesticides are classified from 1 to 5, according to toxicity. The most frequently used pesticides contain chlorpyrifos, dithiocarbamate and triazole chemical compounds, which are described as “less harmful” or “low toxicity”. For their application, toxic pesticides are mixed with petroleum-based horticultural oil. Moreover, it is important to explain that each plantation uses a variety of chemicals, and that each mother’s residence can be surrounded by several plantations. Considering this, our analysis follows Larsen et al. (2017) and we aggregate the pesticides with high and low toxicity affecting each plantation.

An important aspect for the first identification strategy of the paper is that pesticides are applied more intensively during the winter season because the high humidity and frequent rainfall favor the spread of *Sigatoka Negra*. As the rainy season is not equal across provinces, fumigations are used with different intensities across Ecuadorian provinces and municipalities. Figure 2.2 shows aerial fumigations in the provinces with a higher concentration of banana plantations. We observe that the use of pesticides is more intense during the rainy season in Los Rios and Guayas, whereas fumigations are more regular in El Oro.

Fumigations must follow strict regulations set by law.[16] Specifically, they cannot be applied under high temperatures, humid conditions, or when wind speed is high. In our study, we assume that fumigations are not applied in strong winds, which implies that exposition to fumigations does not depend on wind direction (Appendix B presents an analysis confirming that aerial fumigations of banana plantations are negatively related to wind intensity). Note also that our exposure variable considers the area of the plantations surrounding the mother’s residence. As a result, winds could have different effects on mothers, depending on the location of the plantations.

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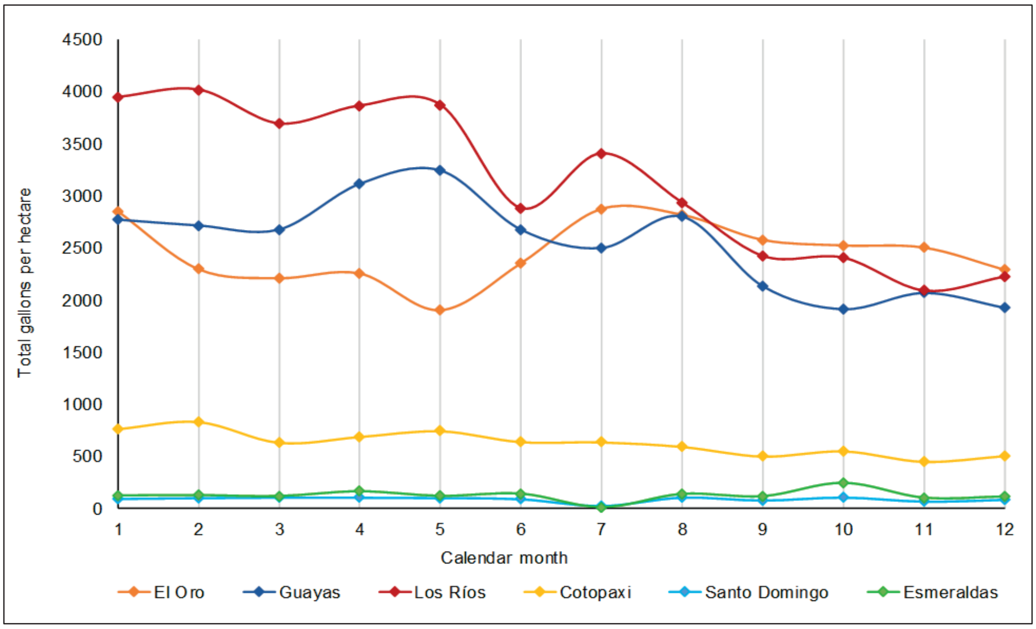
[15] If we include the petroleum-based horticultural oil and water used to mix the agrochemicals, the quantity applied in 2014 escalates to 13 million gallons. Notwithstanding, according to the register, the most harmful pesticides containing dithiocarbamate are sprayed mostly without water dilution.
[16] According to the *Registro Oficial* No. 431 (February 4th, 2015), aerial fumigations cannot be applied when: a) the temperature inside the plantations exceeds 30ºC; b) the relative humidity is greater than or equal to 70%; c) the wind speed exceeds 8 km/h; d) there is a sheet of water on the leaves; e) there are drops of water covering 60% or more of the leaf surface; f) there was rainfall within one hour before the application and, g) there is an inversion phenomenon (fog) limiting visibility during flights.

Figure 2.2 - Seasonal application of pesticides in 2014 (gallons per hectare)



Source: Dirección General de Aviación Civil, GDAC.

The aerial fumigations register has at least three relevant limitations. First, the information refers to 2014, that is, one year before our information on health outcomes starts. However, the year 2014 is not atypical, and we use it to approximate the seasonal changes in the use of pesticides (BCE, 2017; PRAS, 2014). Second, although we have the precise coordinates of each fumigation application, we are unable to determine if pesticides are applied to one particular plantation or to a group of plantations with the same or different owners. Indeed, owners of small and medium plantations usually jointly contract fumigation services to reduce costs. To address this problem, we use the information in the register to calculate the gallons of pesticides sprayed in each municipality in each month (a similar approach is adopted in Gemmill et al., 2013, and Larsen et al., 2017). We then assign these gallons to the plantations of each municipality according to their area in square meters (See Appendix C for more details). As a result, we use two variables that measure newborns' exposure to fumigations, one that only accounts for the square meters of aerially fumigated plantations (based on the MAGAP banana register) and another one that uses the square meters of aerially fumigated plantations, adjusted by the use of pesticides in the municipality (according to the 2014 GDAC register). Finally, another limitation of the fumigation register is that it does not contain information on other crops. In light of this, we do not use this register in our second identification strategy, when we compare the health effects of banana plantations and of other crops.

2.4 Empirical strategy

The aim of our paper is to analyze the causal effect of pesticides used in banana plantations on birth outcomes. One difficulty of this analysis is that unobserved socio-economic characteristics of the families might affect both the location of their residence and newborns' health outcomes. This will lead to biased estimates of the effect of pesticides. We adopt different strategies to overcome the identification challenges posed by economic correlates. First, we create a measure of exposure to pesticides that reflects the density of aerially fumigated plantations in the surroundings of the mother's residence. We use this measure to classify newborns as exposed and not exposed to pesticides. Second, we use this classification of newborns to implement three estimation designs to identify the causal effects of pesticides. Specifically, we exploit seasonal variations in the fumigation of banana plantations, we consider differences in the use of fumigations across crops, and we adopt a maternal fixed effects approach to account for time-invariant differences across mothers who had more than one child in the period 2015-2017 and that had different residences during each pregnancy (i.e., we examine siblings that had different levels of exposition to pesticides during pregnancy).

Exposure analysis

We define exposure to pesticides as living in an area with a high presence of fumigated plantations. To measure newborns' exposure, we use geographical buffers that calculate the square meters of plantations surrounding the mother's residence during pregnancy. Using the precise address of the mother and the perimeter of the aerially fumigated plantation, we calculate, for each mother, 25-meter-radius buffers from their position up to 2.5 kilometers. In each buffer, we calculate the square meters of banana plantations, which may be fumigated manually or with an aircraft. Appendix C presents a detailed explanation of how we calculate the buffers. We then weight and aggregate the resulting 100 buffers for each mother to construct our exposure variable. The following kernel function represents the weights given to the buffers,

$$Weight = \frac{1}{1+\left(\frac{a}{c}\right)^{b}}, \tag{1}$$

where a is the buffer's radius, b is the steepness and c is the cut-off value at which the decaying function starts to decrease more rapidly. The steepness parameter b determines how quickly the effects of pesticides decay as we move away from the perimeter of the plantation, and the cut-off parameter c reflects the distance at which there is an inflexion in the decaying function. If fumigations are administered in the absence of wind and at a low height over the banana trees, the pesticides will not spread far from the perimeter of the plantation and exposure should quickly decay. Otherwise, pesticides can spread across larger distances. We calculate for each mother 100 buffers of 25 meters assuming that exposure completely vanishes beyond 2.5 kilometers. Moreover, we follow the literature on air pollution (Currie et al., 2009; Currie et al., 2015; Gemmill et al., 2013; Larsen et al. 2017; Gibbs et al., 2017; Dereumeaux et al., 2020) and consider that most of the effect of pesticides is concentrated in the area close to the plantations and that the effects quickly decay with the distance. Figure 2.C6 in Appendix C illustrates different combinations of the parameters b and c for the weighing function in (1). The weights we use in our analysis imply that most of the effect of pesticides is concentrated in the 50, 100 or 250 meters from the perimeter of the plantations. The analysis of the exposure that we conduct in section 5.2 will help us to determine the values of parameters b and c that are better adjusted to our case. More specifically, we use the following model to examine the distance at which pesticides affect birth outcomes:

$$Y_{ijmy} = \theta ExposureBuffers_i + \beta X_i + \mu_j + \psi_m + \phi_y + \varepsilon_{ijmy} \quad (2)$$

where Y_{ijmy} shows the birth outcomes (i.e., birth weight, low birth weight, gestation weeks, Apgar score) of newborn i, in municipality j, in month m, and year y. $ExposureBuffers_i$ is the continuous variable capturing the sum of the 100 weighted buffers reflecting the area (in square meters) of fumigated plantations close to the mothers' residences. X_i is a group of children and mother control variables. The model also includes municipality (μ_j), month (ψ_m), and year fixed effects (ϕ_y) to control for non-pollution spillovers that can be related to the agriculture activity and the weather. Finally, we assume the error term ε_{ijmy} to be iid and normally distributed. The coefficient θ shows an estimate of the effect of exposure to pesticides on birth outcomes. Our analysis will identify the values of the decaying function in (1) that better adjusts to this equation.

Other studies have used similar tools of geographic information systems (GIS) to sum the pesticides applied within different radial distances between agricultural lands and households (Cockburn et al., 2011; Gemmill et al., 2013; Li et al., 2005; Reynolds et al., 2004; Rull et al., 2009). In Gemmill et al. (2013), the exposure to pesticides (methyl bromide) is calculated by summing the kilograms of pesticides applied in all 1.6 km^2 Public Land Survey System (PLSS) sections that fell within 5 km of the maternal residence. The authors sum these totals over each day of a trimester interval, yielding an estimate of the total amount of methyl bromide (kilograms) applied within 5 km of the maternal residence during each trimester of pregnancy. In Larsen et al. (2017), exposure is measured as kilograms of active ingredients applied in the 2.6 km^2 PLSS section encompassing the mother's address. One advantage of our analysis over these studies is that we can use the exact perimeter of the aerially fumigated banana plantation and for this reason we have accurate measures of the number of square meters fumigated close to the mothers' residences.

Seasonality analysis

Banana plantations are fumigated throughout the year to maintain the continuous production and exports of the banana fruit. However, fumigations are more intense during the rainy season when humidity conditions favor the propagation of *Sigatoka Negra*. Using the national registry of pesticides, we observe that the intensification of fumigations and pesticides quantities varies across provinces (Figure 2.2). In Los Rios, fumigations are more important between January and July, in Guayas, between March and June, and in El Oro, between July and September. In other provinces such as Cotopaxi and Manabí, fumigations are much less frequent and there is little variation in their intensity. We use these seasonal patterns to estimate a DID model comparing the difference between newborns living in exposed areas in intense and non-intense fumigations seasons during gestation, relative to the difference between newborns living in not exposed areas in the same two seasons. We estimate the following model:

$$Y_{ijpmy} = \beta_0 + \beta_1 Banana\ Exposure_i + \sum_{z=1}^{3} \beta_z Z^{th}\ Intense\ Fumigations_{ip} + \sum_{z=1}^{3} \theta_z\ Banana\ Exposure_i * Z^{th}\ Intense\ Fumigations_{ip} + \delta X_i + \mu_j + \psi_m + \phi_y + \varepsilon_{ijpmy} \quad (3)$$

where Y_{ijmy} shows the birth outcomes of newborn i, in municipality j, month m, and year y. $Banana\ Exposure_i$ is a dummy variable that takes the value 1 for newborns from mothers highly exposed to pesticides, where high exposition will be determined according to the results of the previous section. In particular, we will consider that newborns are highly exposed to fumigations if they satisfy two conditions: (1) they have a weighted buffer above the average level at 100 meters distance; and (2) they are located within 100 meters of the closest plantation.[17] The variable $Z^{th}\ Intense\ Fumigations_{ip}$ is a dummy variable that takes the value 1 for newborns that were affected by high-intensity fumigations in their province of residence p, during their Z^{th} gestation trimester. We construct this variable taking into account the fumigation patterns observed in each province and the newborns' respective gestation stages.

Our parameter of interest is θ_z (the DID parameter), which captures the change in the birth outcome generated by an increase in the intensity of fumigations when the exposed newborn was in the Z^{th} gestation trimester. This identification strategy exploits the time variations of fumigations across provinces and the differing seasonal prenatal exposure to pesticides. This approach has been used in other papers to examine the effect of fertilizers on water sources (Brainerd and Menon, 2014) and in the medical literature to analyze the effects of pesticides (Bradman et al., 2003, 2011; Cecchi et al., 2012; Laborde, 2015). One general finding is that children exposed to higher concentrations of agrichemicals during the first gestation trimester experience worse health outcomes across a variety of measures.

Comparison with other crops

Our second research design considers a DID model that compares the difference between mothers exposed to the fumigations of banana plantations and those not exposed, relative to the difference between mothers exposed and not exposed to any other crops. To do so, we estimate the following model:

$$Y_{ijmy} = \beta\ Crops\ Exposure_i + \theta\ Crops\ Exposure_i * Banana\ Exposure_i + \delta X_i + \mu_j + \psi_m + \phi_y + \varepsilon_{ijmy} \quad (4)$$

where $Crops\ Exposure_i$ is a dummy variable that takes the value 1 for newborns from mothers exposed to any crop (banana, rice, corn, and cocoa), where the variable exposure is constructed as in the previous section. Exposed mothers are those whose weighted buffer is above the average level at 100 meters distance, and that are located within 100

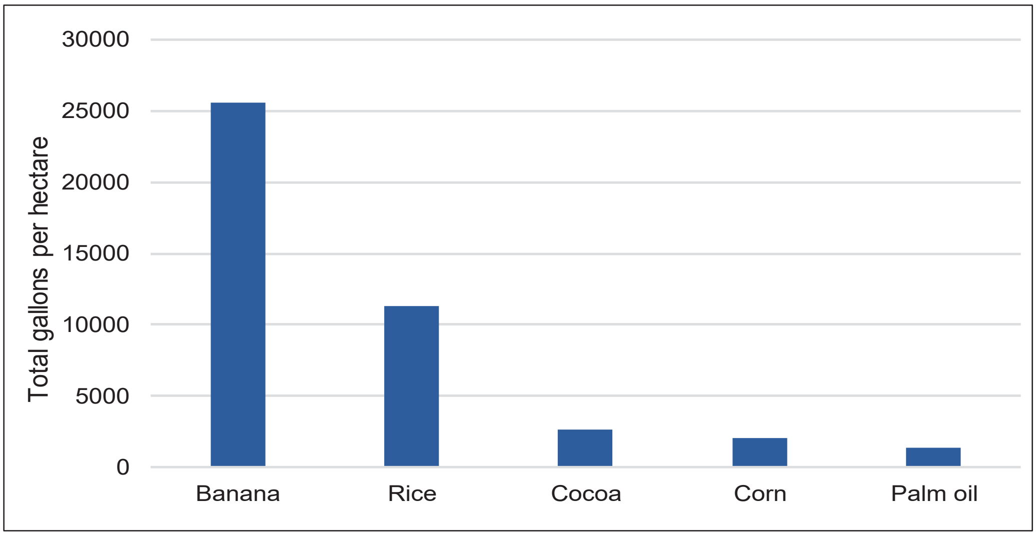
[17] The use of a binary measure of exposure is justified because the functional form of the relationship between pesticide exposure and birth outcomes is not well understood and could be nonlinear (Larsen et al., 2017).

meters of the closest plantation. The variable $Banana\ Exposure_i$ is the same than in the previous section. This model also considers several newborn and mother control variables, as well as municipality and birth cohort fixed effects.

The coefficient of interest in this model is θ, which shows differences in birth outcomes between newborns exposed to banana plantations and newborns exposed to any other crop, due to the effect of fumigations. Note that an essential assumption of this analysis is that there are no relevant differences between mothers living close to banana plantations and those living close to other crops. Table 2.1 presents mean maternal and newborn characteristics for newborns exposed to banana plantations and for those exposed to rice, corn, and cocoa. We find statistically significant differences for some crops and for some relevant characteristics such as mother's age, prenatal control sessions, education, or social status. However, most of these differences disappear when we repeat the analysis at the province level (see Tables 2.D1 to 2.D3 in Appendix D) or at the municipality level (not reported, for simplicity). Therefore, potential non-pollution spillovers are controlled with the consideration of municipality and birth cohort fixed effects.

Another important assumption for the identification is that aerial fumigations are much more important for banana plantations than for the other crops. Figure 2.3 supports this situation by comparing gallons applied per hectare for the crops considered in our analysis. Considering these differences, our analysis will determine whether the more intensive use of pesticides in banana plantations has a differential effect on newborns' health.

Figure 2.3 - Gallons of pesticides per hectare for crops in coastal provinces (2015-2017)



Source: Encuesta de Superficie y Producción Agropecuaria Continua (INEC).

Maternal Fixed Effects

Our third empirical strategy uses mothers' identifiers in our birth records data to link siblings born to the same mother and estimates a maternal fixed effects model. Following a similar approach by Currie et al. (2020), we analyze the effects of pesticides focusing on those mothers who had two or more children in the period examined, and we exploit the fact that a portion of these mothers report different residences for each of the pregnancies. We consider the following model:

$$Y_{ijmyk} = \theta\ Banana\ Exposure_i + \beta X_{ik} + \delta_k + \mu_j + \psi_m + \phi_y + \varepsilon_{ijmy,} \qquad (5)$$

Where k is the mother's indicator. As in the first identification strategy, the variable $Banana\ Exposure_i$ is a dummy variable that takes the value 1 for newborns highly exposed to pesticides during the gestation period. The vector of control variables X_{ik} includes birth order and birth interval dummies: first birth, less than 12 months from previous birth, 12-24 months from previous birth, and 24-36 months from previous birth. On the other hand, δ_k is the maternal fixed effect that accounts for newborns that have the same mother. The key coefficient of interest in equation (5) is θ, which we identify using 852 newborns from 422 mothers who had at least one pregnancy in a residence highly exposed to aerial fumigations, and one pregnancy in a residence not exposed to pesticides.[18] Finally, note that in this model we cluster standard errors at the mother level.

[18] Out of approximately 51 thousand newborns considered, some 6% are from a mother with at least two pregnancies and 3% (1,351) from a mother with at least two pregnancies who resided at a different address for each pregnancy.

2.5 Results

2.5.1 Exposure to pesticides

This sub-section estimates the model in equation (2) to analyze the relationship between newborns' birth weight and the variable $Exposure\, Buffer_i$ that measures area of fumigated banana plantations surrounding the mothers' residence. We will then use the results from this analysis to construct the dummy variable $Banana\, Exposure_i$ that identifies newborns exposed and not exposed to pesticides, and that we employ in the causality study of the next sections.

Table 2.2 reports the results of our estimations, applying different values of b and c to construct the variable $Exposure\, Buffer$. In particular, we consider that b can take the value of 4, 6, 10 or 15, where a low value implies that pesticides spread over a wider area after their application, and a high value means that pesticide droplets fall almost vertically over the banana trees. Moreover, we consider that c can take the value of 50, 100 or 250 meters, where larger values mean that pesticides fall further away from the perimeters of the plantations. In panel A in the table, the exposure variable considers the square meters of fumigated plantations and in panel B it considers the log of the gallons of pesticides applied in each square meter of the plantations. All regressions include newborn and mother controls, as well as municipality and birth cohort fixed effects. Moreover, the regressions include all mothers located at a distance of up to 2.5 kilometers from the plantations.

The results reveal that the mother's exposure to pesticides, measured with the weighted buffers, is negatively associated with newborns birth weight. Interestingly, high values of b and low values of c derive higher coefficients. Specifically, we find that the effects of pesticides are mostly concentrated at approximately 100 meters from the plantation perimeters and those effects decrease rapidly with distance. These results suggest that pesticides generate an average birth weight reduction of 12 grams and 15 grams, at a distance of 100 meters and 50 meters, respectively, from the plantation perimeter. Notice that our findings do not mean that fumigation firms do not respect the protection distance imposed by the law, as it could be that the regulated distance is not enough to protect the neighboring population.

Tables 2.D4 and 2.D5 in Appendix D show the results of the baseline model in equation

(2) when we use separate samples for girls and boys. The right-hand panel in each table shows the estimates when we restrict the sample to births with a normal delivery, as a C-section can modify the duration of the gestation period. We find that results are stronger and statistically significant when we restrict the sample to births with a normal delivery. On the other hand, Tables 2.D6 and 2.D7 repeat the analysis, considering mothers' education levels and shows that the negative effect of pesticides on birth weight is stronger for newborn girls whose mothers have only basic or no education. Pesticides negatively affect newborn boys, but the reduction in birth weight is not statistically significant.[19]

Finally, we use the results from these analyses to construct the dummy variable $Banana\ Exposure_i$ that we consider in the causality analysis to group the newborns into exposed and not exposed to pesticides. Specifically, we establish that the variable $Banana\ Exposure_i$ takes the value 1 for mothers who reside within 100 meters of the plantation perimeter and with a weighted buffer above the average of the mothers living within this distance. We construct this variable using the values $b = 4$ and $c = 100$, so we assume that pesticides have a large effect on the population living within 100 meters of the plantation perimeter and that the effects quickly vanish with greater distance.

2.5.2 Effects of pesticides on health at birth

Seasonality analysis

Table 2.3 presents the estimates of the DID model in equation (3) that analyzes the effects of the seasonal intensification of fumigations on newborn health outcomes. Columns (1) and (4) show that, when the first gestation trimester occurs during the months of intensive fumigations, the birth weight of exposed newborns is reduced by 37.7 grams and the likelihood of low birth weight (LBW) increases by 0.35 (with an odds ratio of 1.41).[20] Moreover, column (9) shows that when the third gestation trimester occurs during the months of intensive fumigations, the likelihood of a low Apgar score at first minute increases by 0.33 (with an odds ratio of 1.39).[21] We do not find a significant impact of the

[19] We have repeated this analysis calculating the variable $Exposure\ Buffer$ considering the volume of pesticides applied in gallons per hectare in each municipality in 2014, as in panel B of Table 2.2. The results obtained (not reported, for simplicity) are similar to those shown above. Likewise, we find that the effect of pesticides is more concentrated within 100 meters of the plantations and that girls born to less educated mothers is the most affected group.
[20] We define low birth weight (LWB) as lower than 2,500 grams.
[21] We define low Apgar score at first minute as lower than or equal to 6, a normal score being 7 or above.

interaction terms on the number of gestational weeks or on the preterm (premature birth) dummy variable.

Tables 2.4 to 2.6 present some further results for the birth weight outcome variable. Table 2.4 considers separately the effects of the seasonal intensification of fumigations in each gestation trimester. Column (1) is the baseline model and shows that exposure to pesticides reduces birth weight by 23.5 grams. Columns (2) to (4) present the results of the DID model for each gestation trimester. We find that birth weight is reduced by 37.3 grams when the first gestation trimester coincides with the months of intensive use of fumigations, but we do not find a statistically significant effect for the other two trimesters. Finally, column (5) reproduces column (1) in Table 2.3 and shows the effect of the seasonal intensification of fumigations at different trimesters of gestation. The results confirm that fumigations have the most impact when they occur during the first gestation trimester. At this point, it is important to clarify that these estimates reflect the effects of the seasonal increases of fumigations in the group of exposed newborns, so the overall impact of pesticides on birth weight can be higher.

Seasonal variation in the use of pesticides is more evident in the province of Los Rios, which experiences a substantial increase in fumigations during the rainy season and the months that follow (Figure 2.2). To further examine the seasonal effects of pesticides, Table 2.5 repeats the DID model in equation (3), focusing on this province. Results in column (2) confirm that pesticides have a negative and significant effect on newborns that are more exposed to fumigations during the first trimester of gestation, and results in column (3) reveal that they also have an effect on those exposed in the second trimester. However, all newborns for whom the second trimester of gestation coincides with the rainy period have a higher birth weight, a factor that partly compensates for the effect of pesticides in the exposed group. Finally, column (5) shows that in Los Rios, newborns exposed to intensive fumigations in the first and second trimesters of gestation have an aggregated birth weight deficit of 89 grams compared to those newborns that are also exposed to fumigations but not in these trimesters of gestation.

Finally, Table 2.6 presents the heterogeneous results of seasonal fumigations considering the mother's education level and the sex of the newborn. Column (1) shows that newborns with less educated mothers that are exposed to intensive fumigations have a birth weight that is 44.4 grams lower than those not affected, but column (2) does not find a significant effect of seasonal intensification of fumigations on birth weight. On the other hand, while the estimates in column (3) do not find a significant effect of pesticides on newborns from more educated mothers, column (4) finds a birth weight effect of 50.2 grams for those exposed to intense fumigations in the first trimester of gestation. Regarding sex differences, column (5) shows that girls exposed to pesticides have a birth weight that is nearly 31.8 grams lower than those not exposed, and column (6) shows an effect of 50.3 grams on newborn girls exposed to intensive fumigations in the first gestational trimester. Finally, our estimates in columns (7) and (8) show no significant effect of exposure to fumigation on male newborns.[22]

Comparison with other crops

Table 2.7 presents the main results of our second identification strategy, which compares the difference between infants born to mothers exposed to the banana plantation fumigations and those not exposed, relative to the difference between those born to mothers exposed and not exposed to any other crops (rice, corn, and cocoa). The variables $Banana\ Exposure_i$ and $Crops\ Exposure_i$ are constructed as in the previous empirical design. Both dummy variables take the value 1 for mothers who reside within 100 meters of the perimeter of a plantation (banana or another crop) and with a weighted buffer above the average within that area. Column (1) considers the results for the whole sample and suggests that newborns exposed to fumigated banana plantations have a birth weight deficit of 29.3 grams compared to those exposed to other crops. Columns (2) and (3) consider separate samples for those born to less educated and more educated mothers, respectively. The estimates show that exposure to fumigations of banana plantations has a negative and significant effect of 76.9 grams on those born to less educated mothers and a positive but not significant effect on those born to more educated mothers. Table 2.8 presents separate regressions for newborn girls and boys. Columns (1) and (2) show negative and similar coefficients for the two groups, although they are not statistically significant. Columns (3) and (4) restrict the analysis to newborns with less educated mothers and show that among this group, girls exposed to fumigated banana plantations have a birth weight deficit of 71.7 grams compared to girls highly exposed to other crops. We obtain a similar coefficient for boys, although it is not significant. To sum up, our results show that being close and highly exposed to aerially fumigated banana plantations during pregnancy entails an important detriment to health at birth, especially for newborn girls whose mothers have only basic or no education.

Maternal fixed effects

Tables 2.9 to 2.13 show the results from the maternal fixed effects model in expression

[22] Our results are consistent with previous evidence that shows newborn females are more responsive than males to environmental shocks, due to a combination of biological and social factors (Ross and Desai, 2005; Maccini and Yang, 2009; Barron et al., 2017).

(5). Specifically, we restrict the sample to those mothers giving birth to two or more children in the period 2015 to 2017, and we exploit the fact that a portion of these mothers had a different address when they registered each birth. Tables 2.9 and 2.10 show the results when we use the continuous variable $Exposure\ Buffer_i$, which captures the sum of the 100 weighted buffers considering the square meters of the plantation surrounding the mother's residence, as explained before. Table 2.9 considers different combinations of the parameters b and c to construct the exposure variable. Although all coefficients are negative, as expected, we do not find a statistically significant effect of pesticides on birth health. However, Table 2.10 analyzes girls and boys separately, showing that exposure to pesticides has a negative and significant effect for newborn girls. Considering the average value of the exposure variable, the calculated coefficient implies a birth weight deficit of between 70 and 200 grams, depending on the combination of parameters used to construct the buffer.

In Tables 2.11 and 2.12 we repeat the previous analysis, but now the variable $Exposure\ Buffer_i$ reflects the volume of pesticides (gallons per square meter) applied to the plantations of each municipality, according to the patterns in the use of pesticides calculated with the 2014 fumigation register. This measure allows us to control for the different intensities of pesticide use across geographical areas. The results obtained are qualitatively similar to those of the previous tables, although the coefficients are not directly comparable.

Table 2.13 shows the results of the model in equation (5) when we use the dummy variable $Banana\ Exposure_i$ to identify newborns exposed and not exposed to pesticides. As before, we do not find a significant effect of exposure to pesticides on birth weight when we consider the whole sample. However, columns (2) and (5) show a significant and very large coefficient when we focus on the effect of pesticides on newborn girls. Specifically, our results show that those girls highly exposed to pesticides during pregnancy have a birth weight that is around 500 grams lower than their non-exposed female siblings. One explanation for this large coefficient is that girls exposed to pesticides during pregnancy had a gestation period that was two weeks shorter than that of their siblings (we do not present these results for simplicity), a situation that implies a profound effect on the birth weight. Taking this into account, the right-hand panel of Table 2.13 repeats the analysis, controlling for the number of gestational weeks. After this adjustment, we find that newborn girls exposed to pesticides in utero have a birth weight that is 346 grams lower than their non-exposed female siblings. This effect is still larger than the one we have found in the previous identification strategies. Note that in the first identification approach we consider the effects of the seasonal intensification of fumigations in a group of newborns that are all exposed to pesticides. In this case, by contrast, the identification consists in comparing siblings exposed and not exposed to pesticides. Therefore, the effect of pesticides is expected to be greater in this case.

Finally, it is important to mention that the different impact of pesticides on newborn girls and boys may be related to gender differences in the survival probability in front of adverse environmental conditions. The medical literature has shown that detrimental conditions during pregnancy increase the probability of spontaneous abortions, finding a smaller probability of abortions on female fetuses (Byrne et al., 1987; Hobel et al., 1999; Zaren et al. 2000; Ghosh et al., 2007; Del Fabro et al., 2011; Pongou, 2013; Buckberry et al., 2014). In accordance with this result, we observe that in the period examined the share of female siblings born in non-exposed areas was of around 48.5%, while their share in exposed areas was larger than 52%. This situation suggests that pesticides may reduce the survival probability of male fetuses in exposed area, but the birth weight of surviving newborn boys in exposed and non-exposed areas is not statistically different. Finally, it is important to explain that there is a scarce medical literature examining the gender differences in the effects of air pollution on birth weight. In a study for Brazil, Nascimento et al. (2017) find that female newborns are more susceptibility to maternal exposure to air pollutants. However, previous studies such as Rückerl et al. (2011) have found ambiguous results.

2.6 Conclusion

Aerial pesticide fumigation plays a key role in the agriculture industry, but its massive and uncontrolled use is causing important health problems in nearby populations. Our paper contributes to the existing economic, medical, and environmental literature by examining the causal relationship between newborns' in-utero exposure to pesticides and adverse health outcomes. In order to do this, we combine precise information on mother's residence during pregnancy, the perimeter of banana plantations and the volume and frequency of pesticide use in Ecuador.

Our analysis is based on a novel measure of newborns' exposure to pesticides. Using the exact address of the mothers during pregnancy and the perimeters of the plantations, we calculate 25-meter-radius buffers of fumigated plantations from the mother's residence up to 2.5 kilometers. Each buffer reflects the square meters of banana plantations affected by aerial fumigation. We then construct our individual exposure measure by weighting the 100 buffers according to a decaying function. Our baseline analysis reveals the existence of a negative relationship between high in utero exposure to pesticides and a set of health outcomes. More specifically, we find that exposure to pesticides during gestation is associated with a birth weight deficit of between 12 and 32 grams, a greater probability of low birth weight and a greater probability of a low Apgar score. The impact of pesticides occurs within the first 50 to 150 meters of the perimeter of the plantation and quickly decreases beyond that distance. We use these results to construct the variable of newborns' exposure to pesticides that we use in our causal analysis. Specifically, we consider that mothers exposed to banana plantations are those with aggregated weighted buffers above the average level at 100 meters away, and that are located within 100 meters of the perimeter of the closest plantation.

We propose three identification strategies to examine the causal effect of pesticides on health at birth. First, we exploit the seasonal variation of aerial fumigations across provinces. For this, we identify the trimester of gestation that occurs during the months of intensive use of pesticides. Then, we estimate a DID model comparing the difference in birth weight of newborns exposed to pesticides in the high and low fumigation seasons, relative to newborns non-exposed to pesticides in the same two seasons. The results reveal that the effects of pesticides are stronger when the first trimester of gestation happens in the months of intensive use of pesticides. Specifically, we find that newborns exposed to pesticides have a birth weight deficit of between 39 and 89 grams if their first trimester of gestation coincides with the seasons of intensive fumigations. These estimates reflect the effect of the seasonal intensification of fumigations in the newborn that are exposed to pesticides, so the overall impact of pesticides on birth weight is expected to be higher.

The second identification strategy follows a DID estimation approach that exploits spatial variation in newborns' exposure to the fumigation of banana plantations and to the fumigation of other crops (rice, corn, cocoa). This model compares the difference in birth outcomes between newborns exposed and not exposed to the fumigations of banana plantations, relative to the difference for newborns exposed and not exposed to any other crops. The results drawn from this model suggest that exposure to fumigation of banana plantations generates a birth weight deficit of between 29 and 76 grams, compared to newborns whose mothers are exposed to the fumigation other crops. The effects are larger for newborn girls and for those with less educated mothers.

Finally, our third empirical strategy consists of a maternal fixed effects model, where we exploit changes of residential address reported by mothers who had two or more children in the period examined. We thus compare different pregnancies of the same mother, in which one newborn was exposed in utero to pesticides and the other not. The results show that newborn girls exposed in utero to pesticides have a birth weight deficit of between 250 and 500 grams, compared to their non-exposed female sibling. One explanation for the great size of the effect is that high exposure to pesticides in pregnancy shortens the gestation period by an average of 2 weeks. Once we adjust our regressions for the number of gestation weeks, we obtain a birth weight deficit of around 346 grams, which is still very relevant.

Our results are in accordance with the findings in medical and environmental papers that examine the effects of pollutants on health at birth. Our effects are much larger than the 30 grams obtained by Bozzoli and Quintana-Domeque (2014), when they analyzed the effects of the economic crisis in Argentina, or the 23 grams found by Range and Vogl (2019), who examined the effects of the fire pollution caused by sugar cane harvesting in Brazil. However, our findings are close to the 200-gram effect found for mothers that smoke (Kramer, 1987; Lindbohm et al., 2002) and to the 107-175-gram impact obtained by Burlando (2014) examining the consequences of an unexpected blackout in Tanzania. We also confirm the finding obtained in previous studies of air pollution showing a larger impact in the first trimester of gestation (Almond et al., 2011; Bozzoli and Quintana-Domeque, 2014; Burlando, 2014).

We believe that this research can help to improve the design of public policies regarding fumigation practices in different plantations across the world and can be used to enhance pregnancy protocols in affected regions. Our conclusions reinforce the argument that is necessary to modify the use of agrochemicals in agriculture and to increase the protection for neighboring populations and the plantation workers. We have shown that in Ecuador, aerial fumigations have a very relevant impact on the health of newborns born in close proximity to the banana plantations. Our results highlight the urgency of enforcing and reviewing the protection distances established in the country's legislation in 2012 and 2015, to safeguard the health of the population living near the plantations.

Tables of Results

Table 2.1 – Maternal characteristics by exposure to banana plantations and to other crops

Variable	Banana (1)	Rice (2)	Diff (3) (2) - (1)	Banana (4)	Corn (5)	Diff (6) (5) - (4)	Banana (7)	Cocoa (8)	Diff (9) (8) - (7)
Birth weight	3149.9	3051.47	-98.427***	3149.9	3085.82	-64.08***	3149.9	3132.77	-17.132
	(8.07)	(8.53)	(11.739)	(8.07)	(6.83)	(10.505)	(8.07)	(7.63)	(11.099)
Apgar score 1 minute	7.91	8	0.095***	7.91	8.01	0.102***	7.91	7.9	-0.011
	(0.02)	(0.02)	(0.025)	(0.02)	(0.01)	(0.021)	(0.02)	(0.01)	(0.022)
Mother's age	24.18	24.92	0.746***	24.18	24.17	-0.004	24.18	24.2	0.025
	(0.10)	(0.11)	(0.148)	(0.10)	(0.09)	(0.137)	(0.10)	(0.10)	(0.143)
Female newborn	0.48	0.49	0.008	0.48	0.47	-0.011	0.48	0.48	0.003
	(0.01)	(0.01)	(0.011)	(0.01)	(0.01)	(0.010)	(0.01)	(0.01)	(0.011)
Mother's education Less than HS	0.47	0.42	-0.047***	0.47	0.43	-0.036***	0.47	0.44	-0.029***
	(0.01)	(0.01)	(0.011)	(0.01)	(0.01)	(0.010)	(0.01)	(0.01)	(0.011)
Local ethnic group "Montubio"	0.01	0.06	0.047***	0.01	0.01	0.006***	0.01	0.02	0.016***
	(0.00)	(0.00)	(0.004)	(0.00)	(0.00)	(0.002)	(0.00)	(0.00)	(0.003)
Mestizo	0.97	0.93	-0.039***	0.97	0.95	-0.016***	0.97	0.95	-0.019***
	(0.00)	(0.00)	(0.005)	(0.00)	(0.00)	(0.004)	(0.00)	(0.00)	(0.004)
Normal birth	0.55	0.44	-0.118***	0.55	0.53	-0.019*	0.55	0.52	-0.035***
	(0.01)	(0.01)	(0.011)	(0.01)	(0.01)	(0.010)	(0.01)	(0.01)	(0.011)
C-Section birth	0.45	0.56	0.118***	0.45	0.47	0.019*	0.45	0.48	0.035***
	(0.01)	(0.01)	(0.011)	(0.01)	(0.01)	(0.010)	(0.01)	(0.01)	(0.011)
Non marital union	0.41	0.34	-0.072***	0.41	0.36	-0.051***	0.41	0.4	-0.008
	(0.01)	(0.01)	(0.011)	(0.01)	(0.01)	(0.010)	(0.01)	(0.01)	(0.011)
Single	0.41	0.45	0.043***	0.41	0.44	0.032***	0.41	0.43	0.023**
	(0.01)	(0.01)	(0.011)	(0.01)	(0.01)	(0.010)	(0.01)	(0.01)	(0.011)
Married	0.14	0.18	0.042***	0.14	0.16	0.020***	0.14	0.13	-0.006
	(0.01)	(0.01)	(0.008)	(0.01)	(0.00)	(0.007)	(0.01)	(0.01)	(0.007)
Birth at a public hospital	0.86	0.82	-0.040***	0.86	0.88	0.018***	0.86	0.83	-0.028***
	(0.01)	(0.01)	(0.008)	(0.01)	(0.00)	(0.007)	(0.01)	(0.01)	(0.008)
Number of births	2.29	2.23	-0.063**	2.29	2.19	-0.105***	2.29	2.19	-0.102***
	(0.02)	(0.02)	(0.031)	(0.02)	(0.02)	(0.030)	(0.02)	(0.02)	(0.031)
Number of children	2.33	2.27	-0.062*	2.33	2.21	-0.113***	2.33	2.22	-0.104***
	(0.02)	(0.02)	(0.032)	(0.02)	(0.02)	(0.030)	(0.02)	(0.02)	(0.032)
Prenatal control	5.89	6.4	0.505***	5.89	5.55	-0.345***	5.89	5.93	0.04
	(0.03)	(0.04)	(0.050)	(0.03)	(0.03)	(0.047)	(0.03)	(0.04)	(0.049)
Single birth	0.99	0.98	-0.003	0.99	0.99	0.002	0.99	0.99	0.001
	(0.00)	(0.00)	(0.003)	(0.00)	(0.00)	(0.002)	(0.00)	(0.00)	(0.002)
Observations	4,289	3,913	8,202	4,289	5,279	9,568	4,289	4,458	8,747

Significance levels: * p<0.1 ** p<0.05 *** p<0.01. Standard errors in parentheses

Table 2.2 – Effects of pesticide exposure on newborns' birth weight, 2015 to 2017

	Buffer 2.5 Km – Air fumigated plantations							
	Weighted square meters				Weighted logs of pesticides per square meters			
	b=4	b=6	b=10	b=15	b=4	b=6	b=10	b=15
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure buffers – c=50	-0.0028**	-0.0041**	-0.0048**	-0.0049**	-2.0478*	-2.3972*	-2.6097*	-2.6559*
	(0.0013)	(0.0018)	(0.0021)	(0.0022)	(1.0528)	(1.2288)	(1.3392)	(1.3631)
Exposure buffers – c=100	-0.0006*	-0.0008**	-0.0009**	-0.0009**	-0.6543*	-0.7300*	-0.7657*	-0.7781*
	(0.0003)	(0.0004)	(0.0004)	(0.0004)	(0.3763)	(0.4047)	(0.4220)	(0.4285)
Exposure buffers – c=250	-0.0001	-0.0001*	-0.0001*	-0.0001*	-0.1414	-0.1804	-0.2019	-0.2100
	(0.0000)	(0.0001)	(0.0001)	(0.0001)	(0.1316)	(0.1355)	(0.1389)	(0.1401)
Mother's Controls	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	50,034	50,034	50,034	50,034	50,034	50,034	50,034	50,034
R2	0.0986	0.0986	0.0986	0.0986	0.0986	0.0986	0.0986	0.0986

Notes: Each coefficient corresponds to the result of a different estimation of equation (2), where the dependent variable is the newborns birth weight. The left panel shows the results when *Exposure Buffer* is a continuous variable that represents the sum of the 100 weighted buffers with the square meters of the plantations close to the mothers' residences. The right panel shows the results when *Exposure Buffer* considers the sum of the 100 weighted buffers of the logs of the pesticides spread per square meter in the banana plantations. The values of *b* and *c* consider different parameter combinations for the weighting function in expression (1). The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. The controls of child characteristics are indicators of single birth and sex. The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 137 excluding single observations. The reported R–squared is the same for all the coefficients in each column. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2.3 – Effects of the seasonal intensification of fumigations

	OLS fixed effects						Logit fixed effects		
	Birth weight	Gestation weeks	Apgar 1st	LBW	Preterm	Low Apgar	LBW	Preterm	Low Apgar
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Banana Exposure	-2.7738	-0.0041	-0.0189	-0.0139	-0.0120*	0.0055	-0.2005	-0.1930	0.1259
	(16.4818)	(0.0619)	(0.0385)	(0.0104)	(0.0067)	(0.0083)	(0.1648)	(0.1286)	(0.1621)
Intense fumigation during 1st Trimester	2.4741	0.0295	0.0152	0.0007	-0.0056	0.0027	0.0156	-0.1093*	0.0465
	(7.9533)	(0.0258)	(0.0165)	(0.0038)	(0.0036)	(0.0030)	(0.0577)	(0.0639)	(0.0605)
Intense fumigation during 2nd Trimester	13.1523*	-0.0037	0.0116	-0.0018	-0.0028	-0.0038	-0.0123	-0.0632	-0.0775
	(7.3915)	(0.0267)	(0.0145)	(0.0038)	(0.0035)	(0.0036)	(0.0579)	(0.0621)	(0.0772)
Intense fumigation during 3rd Trimester	-1.3288	-0.0259	0.0032	-0.0009	-0.0001	0.0006	-0.0102	-0.0034	0.0128
	(8.2477)	(0.0322)	(0.0145)	(0.0038)	(0.0037)	(0.0029)	(0.0601)	(0.0688)	(0.0569)
Banana Exposure x Intense fumigation during 1st Trimester	-37.7412***	-0.0481	-0.0313	0.0230***	0.0063	-0.0011	0.3380***	0.1191	-0.0161
	(12.5942)	(0.0388)	(0.0327)	(0.0082)	(0.0070)	(0.0081)	(0.1248)	(0.1321)	(0.1639)
Banana Exposure x Intense fumigation during 2nd Trimester	-16.3853	-0.0437	0.0643	0.0075	0.0043	-0.0044	0.1083	0.0626	-0.0803
	(16.1104)	(0.0603)	(0.0414)	(0.0057)	(0.0055)	(0.0079)	(0.0893)	(0.1183)	(0.1601)
Banana Exposure x Intense fumigation during 3rd Trimester	-0.6532	0.0007	-0.0642	0.0132	0.0001	0.0181**	0.2038	-0.0017	0.3508***
	(17.8733)	(0.0373)	(0.0426)	(0.0099)	(0.0071)	(0.0079)	(0.1487)	(0.1343)	(0.1319)
Mother's control	X	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X	X
Observations	50,034	50,034	50,034	50,034	50,034	50,034	49,941	49,609	49,597
R2	0.0988	0.0900	0.0645	0.0911	0.0747	0.0183			
Pseudo – R2							0.1026	0.0967	0.0396

Notes: Each column shows the results of the estimation of equation (3) for a different health outcome. The interaction terms reflect the effect of the increase of fumigations in the exposed area in newborns that were in their k^{th} gestation trimester. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. The controls of child characteristics are indicators of single birth and sex. The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 137 in columns (1) to (6), 119 in column (7), 109 in column (8) and 106 in column (9), excluding single observations in all columns. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.4 – Effects of the seasonal intensification of fumigations on birth weight: gestational trimester

	Birthweight				
	(1)	(2)	(3)	(4)	(5)
Banana Exposure	-23.5069**	-9.7596	-18.8087*	-31.0144***	-2.7739
	(11.1614)	(12.3109)	(10.3329)	(11.1821)	(16.4818)
Intense fumigation during 1st Trimester		0.1942			2.4742
		(7.3896)			(7.9533)
Intense fumigation during 2nd Trimester			13.8871**		13.1524*
			(6.5082)		(7.3915)
Intense fumigation during 3rd Trimester				-5.7726	-1.3288
				(7.3678)	(8.2477)
Banana Exposure x Intense fumigation during 1st Trimester		-37.3074***			-37.7412***
		(11.2294)			(12.5942)
Banana Exposure x Intense fumigation during 2nd Trimester			-11.4556		-16.3854
			(15.4356)		(16.1104)
Banana Exposure x Intense fumigation during 3rd Trimester				19.8484	-0.6532
				(15.2250)	(17.8732)
Mother's control	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X
Municipality F.E.	X	X	X	X	X
Observations	50,034	50,034	50,034	50,034	50,034
R2	0.0986	0.0987	0.0987	0.0986	0.0988

Notes: The table shows the results of the estimation of equation (3) when the outcome variable is birth weight. Column (1) is the baseline model that considers the effect of exposure to pesticides on birth weight. Columns (2) to (4) consider the separate impact of the seasonal intensification of fumigations in the k^{th} trimester of gestation. Column (5) reproduces column (1) in Table 2.3 and shows the effect of the seasonal intensification of fumigations when they affect newborns in the three trimesters of gestation. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. The controls of child characteristics are indicators of single birth and sex. The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 137 in all columns, excluding single observations. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2.5 – Effect of the seasonal intensification of fumigations on birthweight: Los Rios

	Los Rios province				
	Birthweight				
	(1)	(2)	(3)	(4)	(5)
Banana Exposure	-20.0924	-2.7876	7.8612	-27.2638	47.2821
	(27.4867)	(31.7891)	(26.3086)	(23.1008)	(42.7234)
Intense fumigation during 1st Trimester		-12.9257			-10.6355
		(25.9882)			(25.2770)
Intense fumigation during 2nd Trimester			38.8673**		38.9008**
			(15.9778)		(16.0743)
Intense fumigation during 3rd Trimester				13.7287	15.2558
				(31.2296)	(29.6694)
Banana Exposure x Intense fumigation during 1st Trimester		-30.3843**			-45.5294*
		(11.7539)			(23.8331)
Banana Exposure x Intense fumigation during 2nd Trimester			-44.5594**		-43.7245**
			(20.0411)		(20.8672)
Banana Exposure x Intense fumigation during 3rd Trimester				12.3316	-24.0424
				(15.9628)	(28.5529)
Mother's control	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X
Municipality F.E.	X	X	X	X	X
Observations	20,246	20,246	20,246	20,246	20,246
R2	0.1104	0.1105	0.1107	0.1104	0.1109

Notes: The table shows the results of the estimation of equation (3) when the outcome variable is birth weight. Column (1) is the baseline model that considers the effect of exposure to pesticides on birth weight. Columns (2) to (4) consider the separate impact of the seasonal intensification of fumigations in the k^{th} trimester of gestation. Column (5) reproduces column (1) in Table 2.3 and shows the effect of the seasonal intensification of fumigations when they affect newborns in the three trimesters of gestation. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations located in Los Rios province. The controls of child characteristics are indicators of single birth and sex. The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 42 in all columns, excluding singleton observations. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2.6 – Effects of the seasonal intensification of pesticides on birthweight: Education and Gender

	Birthweight							
	Less educated mothers		More educated mothers		Girls		Boys	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Banana Exposure	-44.4518**	-26.7392	-3.3091	19.5911	-31.8603**	-16.2749	-19.0076	6.3221
	(20.1905)	(30.1091)	(12.9162)	(19.5710)	(14.4437)	(26.7013)	(18.1006)	(25.0906)
Intense fumigation during 1st Trimester		-20.4311		14.5180		13.6563		-6.6211
		(12.4873)		(10.3451)		(12.9564)		(11.2043)
Intense fumigation during 2nd Trimester		2.9774		15.9373*		12.0723		14.6678
		(11.9694)		(9.0687)		(10.8300)		(10.9628)
Intense fumigation during 3rd Trimester		6.4758		-6.1882		10.8593		-11.7099
		(11.5162)		(9.2212)		(11.5918)		(10.3801)
Banana Exposure x Intense fumigation during 1st Trimester		-16.8253		-50.2384***		-50.3446**		-26.2520
		(19.6080)		(18.2161)		(24.8278)		(21.4073)
Banana Exposure x Intense fumigation during 2nd Trimester		-17.3581		-14.3809		2.3782		-33.6492
		(36.5391)		(18.5945)		(20.9934)		(34.0670)
Banana Exposure x Intense fumigation during 3rd Trimester		-10.6241		2.8075		6.2714		-6.8944
		(32.0171)		(15.0813)		(19.5144)		(29.4750)
Mother's control	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	19,403	19,403	30,619	30,619	24,247	24,247	25,777	25,777
R2	0.1071	0.1074	0.1000	0.1004	0.1011	0.1014	0.0836	0.0839

Notes: The table shows the results of the estimation of equation (3) when the outcome variable is birth weight. Columns (1) to (4) consider the mothers' education level and columns (5) to (8) the newborns' sex. Results present the differential impact that the seasonal intensification of fumigations have on each gestational trimester. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations, for all provinces. The controls of child characteristics are indicators of single birth and sex, except for columns (5) to (8). The controls of the maternal characteristics are mother's age, maternal education dummy (except for Columns (1) to (4)), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorians, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The number of clusters in each sub-panel are 121, 131, 128, and 127, respectively. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.7 – Exposure to banana plantations vs exposure to other crops: mother's education level

	All newborns	Less educated mothers	More educated mothers
	(1)	(2)	(3)
Banana exposure	-29.3733*	-76.9915***	24.9058
	(17.6771)	(27.8066)	(19.3826)
Exposure crops	7.2734	41.9596*	-33.8004
	(17.0594)	(24.5697)	(21.6661)
Mother's Controls	X	X	X
Month x Year F.E.	X	X	X
Municipality F.E.	X	X	X
Observations	50,034	19,403	30,619
R2	0.0986	0.1073	0.1001

Notes: The table shows the results of the estimation of equation (4) when the outcome variable is the birth weight. Column (1) compares the difference between newborns exposed to the fumigations of banana plantations and those not exposed, relative to the difference for newborns exposed and not exposed to any other crops (rice, corn and cocoa). Columns (2) and (3) repeat the analysis for less educated and more educated mothers. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. The controls of child characteristics are indicators of single birth and sex. The controls of the maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school) (except for columns (2) and (3)), a dummy indicator of marital status (divorced, separated, widowed, married, single, in union), ethnic group (mestizo, montubio, white, afroecuadorians, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The number of clusters is 137 in column (1), 121 in (2) and 131 in (3). Significance levels: $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$.

Table 2.8– Exposure to banana plantations vs exposure to other crops: gender and mothers' education level

	Girls	Boys	Less educated mothers	
			Girls	Boys
	(1)	(2)	(3)	(4)
Banana exposure	-25.4087	-33.9225	-71.7033**	-75.4684
	(24.7513)	(25.2623)	(34.1460)	(45.5576)
Exposure crops	-8.1384	18.1999	17.9215	57.8429*
	(23.1278)	(20.6558)	(29.8071)	(31.8525)
Mother's Controls	X	X	X	X
Month x Year F.E.	X	X	X	X
Municipality F.E.	X	X	X	X
Observations	24,247	25,777	9,411	9,986
R2	0.1011	0.0836	0.1178	0.0934

Notes: The table shows the results of the estimation of equation (4) when the outcome variable is the birth weight. All columns compare the difference between newborns exposed to the fumigations of banana plantations and those not exposed, relative to the difference for newborns exposed and not exposed to any other crops (rice, corn and cocoa). Columns (1) and (2) examine separately the effect on girls and boys, and Columns (3) and (4) repeat the analysis for less educated mothers. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. The control of child characteristics is the indicator of single birth. The controls for mothers' characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school) (except for columns (2) and (3)), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorians, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The number of clusters is 128 in column (1), 127 in (2), 116 in (3) and 115 in (4). Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.9 – Maternal fixed effect model: exposure buffers (square meters)

	Buffer 2.5 Km – Air fumigated plantations			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)
Exposure buffers	-0.0023	-0.0031	-0.0095	-0.0148
	(0.0024)	(0.0036)	(0.0106)	(0.0172)
Mother's Controls	X	X	X	X
Mother F.E.	X	X	X	X
Month x Year F.E.	X	X	X	X
Municipality F.E.	X	X	X	X
Observations	3,095	3,095	3,095	3,095
R2	0.8474	0.8474	0.8474	0.8474

Notes: The table shows the results of the estimation of equation (5) when the outcome variable is the birth weight. We use *Exposure Buffers* to identify the effect of aerial fumigations on newborns health. *ExposureBuffer* is a continuous variable that considers the sum of the 100 weighted buffers reflecting the square meters of the plantations close to the mothers' residences. In columns (1) and (2) this variable is constructed assuming that c is equal to 100 and that b is equal to 4 and 15, respectively. Columns (3) and (4) consider that c is equal to 50 and b is equal to 4 and 15, respectively. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations and by mothers who had more than one pregnancy registered during the period 2015 to 2017. The controls of child characteristics are indicators of single birth and sex. The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the mother level and are shown in parentheses. The clusters number is 1,534, excluding singleton observations. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2.10 – Maternal fixed effect model: exposure buffers (square meters) and sex

	Girls – Buffer 2.5 Km				Boys – Buffer 2.5 Km			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure buffers	-0.0158***	-0.0268***	-0.0800***	-0.1427***	0.0034	0.0052	0.0155	0.0253
	(0.0043)	(0.0063)	(0.0187)	(0.0318)	(0.0044)	(0.0060)	(0.0168)	(0.0254)
Mother's Controls	X	X	X	X	X	X	X	X
Mother F.E.	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	852	852	852	852	892	892	892	892
R2	0.8950	0.8952	0.8952	0.8953	0.8885	0.8886	0.8886	0.8886

Notes: The table shows the results of the estimation of equation (5) when the outcome variable is the birth weight. We use *Exposure Buffers* to identify the effect of aerial fumigations on the health of newborn girls and boys. *ExposureBuffer* is a continuous variable that considers the sum of the 100 weighted buffers with the square meters of the plantations close the mothers' residences. Columns (1), (2), (5) and (6) calculate this variable assuming that *c* is equal to 100 and that *b* is equal to 4 and 15, respectively. Columns (3), (4), (7) and (8) assume that *c* is equal to 50 and *b* is equal to 4 and 15, respectively. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations and who had more than one pregnancy registered during the period 2015 to 2017. The control of child characteristic is an indicator of single birth. The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, in union), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the mother level and are shown in parentheses. The clusters number is 422 in the left panel, and 444 in the right panel, excluding singleton observations. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.11 – Maternal fixed effect model: exposure buffers (log of pesticides per square meters)

	Buffer 2.5 Km – Air fumigated plantations			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)
Exposure buffers	-5.3800	-6.2770	-14.5031	-17.3417
	(3.8156)	(4.3097)	(10.0628)	(12.1913)
Mother's Controls	X	X	X	X
Mother F.E.	X	X	X	X
Month x Year F.E.	X	X	X	X
Municipality F.E.	X	X	X	X
Observations	3,095	3,095	3,095	3,095
R2	0.8475	0.8475	0.8475	0.8475

Notes: The table shows the results of the estimation of equation (5) when the outcome variable is the birth weight. We use *ExposureBuffers* to identify the effect of aerial fumigations on the health of newborn girls and boys. *ExposureBuffe*r is a continuous variable that considers the sum of the 100 weighted buffers with the log of the gallons of pesticides spread for square meter in the plantations close to the mothers' residences. Columns (1) and (2) consider that this variable is constructed assuming that *c* is equal to 100 and that *b* is equal to 4 and 15, respectively. Columns (3) and (4) assume that *c* is equal to 50 and *b* is equal to 4 and 15, respectively. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations and who had more than one pregnancy registered during the period 2015 to 2017. The controls of child characteristics are indicators of single birth and sex. The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the mother level, shown in parentheses. The clusters number is 1,534, excluding singleton observations. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 2.12– Maternal fixed effect model: exposure buffers (log of pesticides per square meters) and sex

	Girls – Buffer 2.5 Km				Boys – Buffer 2.5 Km			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure buffers	-19.8378***	-26.2669***	-65.6192***	-84.1711***	-0.1693	-0.6410	1.0518	2.4597
	(7.2754)	(7.5375)	(16.2071)	(18.8682)	(8.1443)	(8.6855)	(18.4671)	(20.9750)
Mother's Contrc	X	X	X	X	X	X	X	X
Mother F.E.	X	X	X	X	X	X	X	X
Month x Year F.	X	X	X	X	X	X	X	X
Municipality F.E	X	X	X	X	X	X	X	X
Observations	852	852	852	852	892	892	892	892
R2	0.8945	0.8947	0.8949	0.8951	0.8883	0.8883	0.8883	0.8883

Notes: The table shows the results of the estimation of equation (5) when the outcome variable is the birth weight. We use *Exposure Buffers* to identify the effect of aerial fumigations on the health of newborn girls and boys. *ExposureBuffer* is a continuous variable that considers the sum of the 100 weighted buffers with the log of the gallons of pesticides spread for square meter in the plantations close to the mothers' residences. Columns (1), (2), (5) and (6) consider that this variable is constructed assuming that *c* is equal to 100 and that *b* is equal to 4 or 15, respectively. Columns (3), (4), (7) and (8) assume that *c* is equal to 50 and *b* is equal to 4 or 15, respectively. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations and who had more than one pregnancy registered during the period 2015 to 2017. The controls of child characteristics are indicators of single birth and sex. The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal labor). Standard errors are clustered at the mother level and are shown in parentheses. The clusters number is 422 in the left panel and 444 in the right panel, excluding singleton observations. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

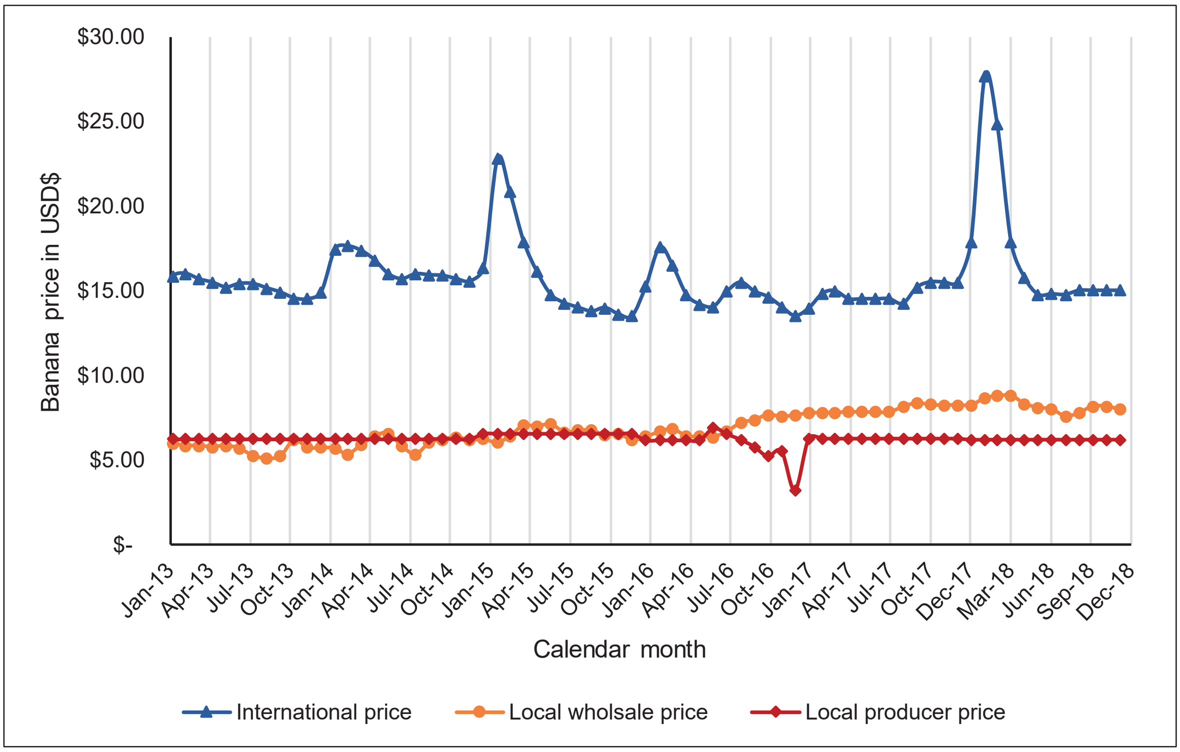
Table 2.13– Mothers' fixed effect model: Exposure dummy

	Birthweight					
	All newborns	Girls	Boys	All newborns	Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Banana Exposure	-31.7435	-578.108***	189.6304	18.5966	-346.8251**	202.1836*
	(93.3755)	(166.1983)	(130.481)	(78.8927)	(158.5531)	(114.3709)
Gestation weeks	-	-	-	X	X	X
Mother's controls	X	X	X	X	X	X
Mother F.E.	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	3,095	852	892	3,095	852	892
R2	0.8474	0.8984	0.8921	0.8950	0.9185	0.9203

Note: The table shows the results of the estimation of equation (5) when the outcome variable is the birth weight. We use the variable *Banana Exposure* to identify the group of newborns exposed to the use of pesticides. *Banana Exposure* is a dummy variable that takes the value of 1 for mothers who reside within the 100 meters to the perimeters of the plantations and have a weighted buffer above the average for the mothers living within this distance. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations and by mothers who had more than one pregnancy registered during the period 2015 to 2017. The right panel includes a control for weeks of gestation. The controls of child characteristics are indicators of single birth and sex (except for columns (2) (3) (5) and (6). The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the mother level and are shown in parentheses. The clusters number for columns (1) and (4) is 1,534, for columns (2) and (5) is 422, and for columns (3) and (6) is 444. Significance level: $^{*} p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$.

Appendix A – Banana prices

Figure 2.A1 - Local and international banana box price



Source: MAGAP – SIPA

Appendix B – Aerial fumigations and wind intensity

Pesticides are applied following strict conditions regulated by law. Specifically, fumigations cannot be applied during high temperatures, humidity conditions, or when wind speed is greater than 8 km/h. We next analyze the relationship between aerial fumigations and severe weather events. Information on temperature, wind and rainfall are obtained from the meteorological institute of Ecuador, "INAMHI", which has 260 weather stations across the country. We focus on 26 stations located in the region of the banana plantations. We combine the 2014 register of aerial fumigation activity and information from INAMHI. We estimate the following model:

$$Y_{jdm} = \theta\ Wind_{jdm} + \mu_j + \psi_m + \varepsilon_{jdm} \qquad (6)$$

where Y_{jdm} shows the number of pesticides applied in municipality j, on day d, of month m. $Wind_{idmt}$ is a dummy variable that takes the value 1 for days with an average wind speed greater than 8 km/h, which is the maximum wind speed that the Ecuadorian legislation allows to fumigate. Note that wind speed can change during the day, generating time intervals in which fumigations may be applied. The model also includes municipality fixed effects, μ_j, and month fixed effects, ψ_m. Finally, we assume the error term ε_{jdm} to be iid and normally distributed. The coefficient θ shows the estimated effect of high wind speed on the number of pesticide applications.

The fumigation register shows that on average each municipality has 3 fumigations per day, although the number of fumigations is higher in the plantations located in Los Rios, El Oro and Guayas. Table 2.B1 shows the results of our analysis on the effect of high-speed winds on aerial fumigations. We estimate a linear regression and a Poisson regression to model count outcomes, given that we do not have zero counts on the outcome variable.[23] The results we obtain show that in days with high-speed winds the frequency of air fumigation is reduced. The OLS analysis in column (4) includes day and month fixed effects and shows that on days with high wind speeds the number of aerial fumigations by an average of 2. Column (8) repeats the analysis with a Poisson model and confirms the negative impact of high wind speeds on fumigations frequency. In terms of magnitudes, we find that on days of high wind speeds fumigations are reduced by 47%, i.e., $(1 - e^{-0.63}) * 100 = 47\%$.

[23] Farmers' decision to fumigate depends mostly on the weather conditions and on the agricultural calendar. Aerial fumigations do not necessarily happen every day, and the registry does not record days with zero air fumigation.

Table 2.B1 – Higher wind speed effects on number of pesticides air fumigation

	OLS – Fixed effects				Poisson – Fixed effects			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Wind	-2.1828**	-2.2050**	-2.1897**	-2.2151**	-0.6211***	-0.6295***	-0.6237***	-0.6332***
	(1.0767)	(1.0860)	(1.0855)	(1.0944)	(0.2161)	(0.0348)	(0.0377)	(0.2208)
Day F.E.		X		X		X		X
Month F.E.			X	X			X	X
Observations	10,844	10,844	10,844	10,844	10,844	10,844	10,844	10,844
R2	0.0264	0.0297	0.0281	0.0316				
Pseudo R2					0.0123	0.0142	0.0133	0.0152

Note: Each coefficient represents a separate regression. Left panel uses an OLS fixed effects estimation. Right panel uses a Poisson fixed effects estimation. Standard errors are clustered at the municipality level, shown in parentheses. The number of clusters is 90 for all columns, excluding singleton observations. Significance at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ level.

Appendix C – Methodology used to construct the exposure measures

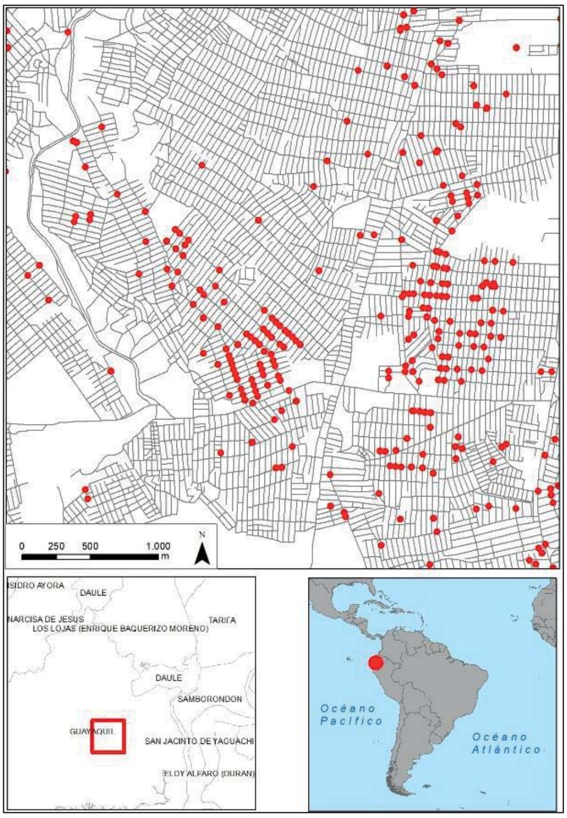
This section explains the methodology used to obtain: (1) the distance from the mothers' households to the crop plantations; (2) the measure of exposure to the crop plantations (banana, cocoa, rice, corn); (3) the measure of exposure to aerially fumigated banana plantations. The software used in these calculations are ArcGis and Qgis.

Distance from the plantations. To calculate the distance from the plantations we first convert the alphanumeric table containing the postal addresses of the mothers into spatial information. We use the API of Google Maps and successfully geolocate the residences of 495,887 newborns out of a total of 955,941 for the period 2015-2017 (Figure 2.C1).

We then calculate the distance from the mother's residence to the closest plantation. For this, we use the *Near* tool of ArcGis. As a result, two new fields are generated in the layer, one that indicates the code of the closest plantation and another one that shows the distance in meters (Figure 2.C2).

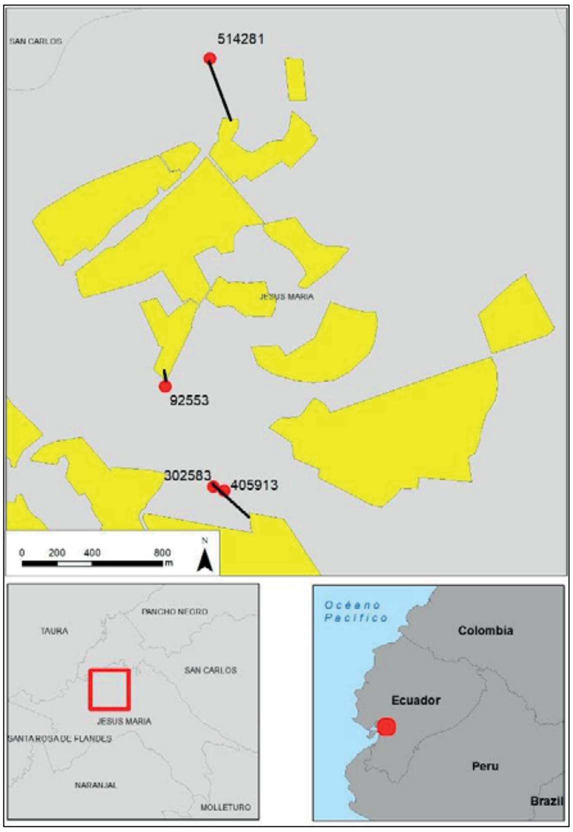
Figure 2.C1 - Alphanumeric data of the newborn (left) and spatial information of addresses (right)

ID	Street address
260444	Batallon YY y la Y
405444	Vacas Galindo entre YY y YY
179444	Sedalana entre la YY y YY
471444	Suburbio LA YY y la Y



Source: Author's elaboration. Data from the newborns registry and the geographic street map.

Figure 2.C2 - Analysis of the closest plantation



ID newborn	Distance (m)	ID Plantation
92553	35.2	3925
302583	187.7	2495
405913	219.2	2495
514281	347.3	2874

Source: Author's elaboration, Data from the newborns registry and the banana plantations census.

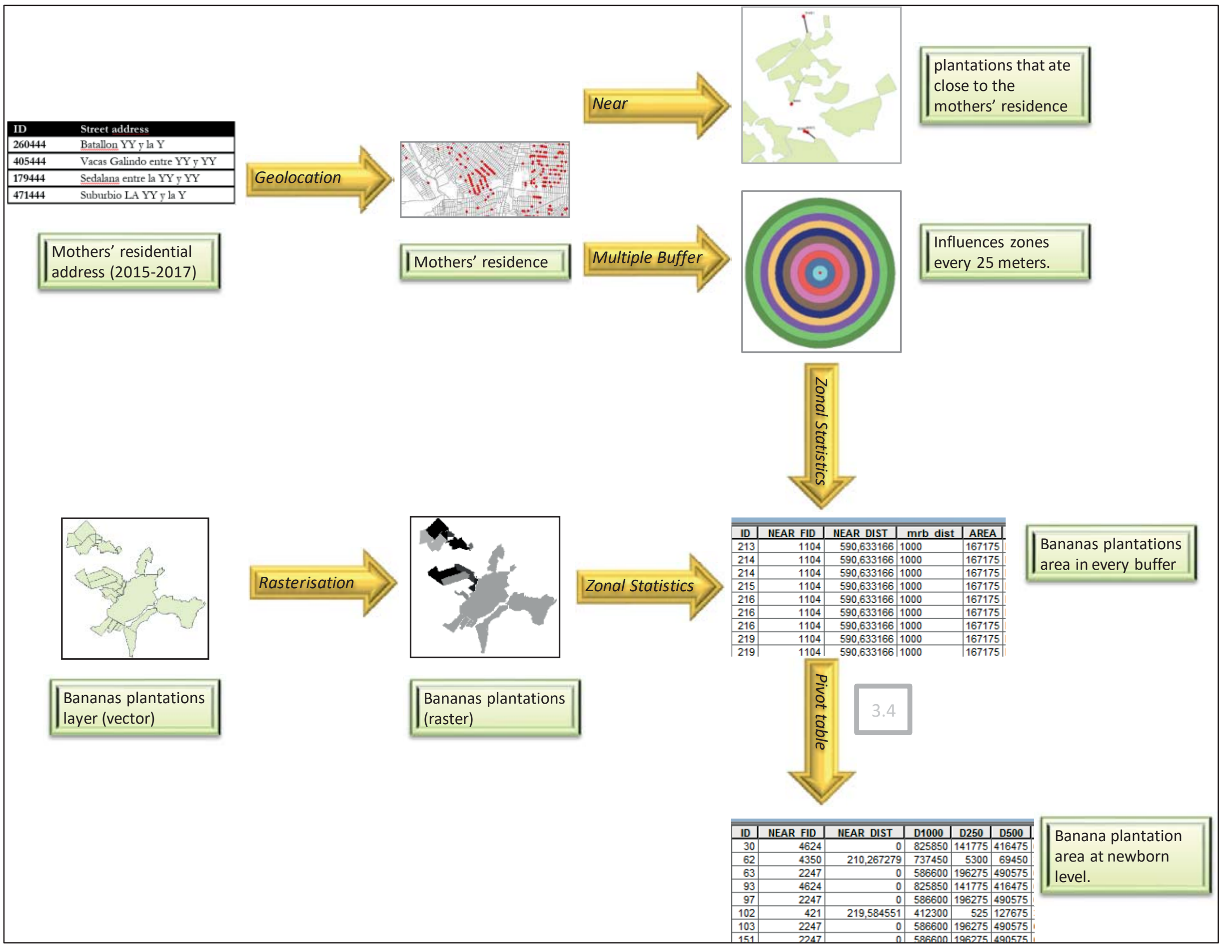
Exposure to the crop plantations. We calculate the area of the plantations that are close to the mothers' households using intervals of 25 meters up to a distance of 2,500 meters (additional analyses have been performed up to 5,000 meters, but the results of our analysis do not change). This process has been repeated for several crops (banana, rice, corn, cocoa). In the case of banana plantations, we also calculate separate measures for plantations that apply aerial and manual fumigations. The analysis requires four steps, combining Qgis and ArcGis software (Figure 2.C3):

1. Generate influence zones (buffers) every 25 meters from the identified address, up to 2,500 meters. We use the Multi Ring Buffer tool of Qgis to create donut buffers (i.e., non-cumulative buffers every 25 meters).

2. As the plantation layer is a vector, we need to transform the plantations layer to a raster format. The plantations layer has to be rasterized with a resolution of 5 meters x 5 meters for each cell to obtain maximum precision for the exposure variable. The process can be used with the Rasterization tool of Qgis, or with the Polygon to Raster tool of ArcGis.

3. Once the plantations are rasterized, we run the *Zonal Statistics* tool of Qgis (the ArcGis software did not work correctly, due to the high number of elements we had to process). This tool gives us the number of pixels of the plantations that are within each 25-meter buffer. When this process is completed, the resulting layer offers a new column that calculates the plantations' surface within each buffer (the number of pixels is multiplied by 25 since they have an area of 5 x 5 meters on each plantations' raster cell). Finally, we transform the information at the subject level using the Pivot tool of ArcGis.

Figure 2.C3 - Exposure analysis



Exposure to fumigated banana plantations. We calculate the amount of pesticides affecting each mother during the gestation period. For this, we determine the pesticides applied in each of the 25-meter buffers calculated for each mother. Due to the absence of data for the period 2015-17, we use the data from the 2014 Register of Aerial Fumigations (General Directorate of Civil Aviation) and create monthly fumigation patterns for each municipality, which are then used for the period 2015-17. The construction of the exposure measure involves the following steps (Figures 2.C4 and 2.C5):

1. We consider the 2014 aerial fumigation points, as provided by the 2014 Register of Air Fumigations. First, we check that the fumigation points spatially coincide with the plantations, finding that 2,317 (3.1%) of the fumigation points do not coincide with the fumigated plantations. Most of the points are repositioned manually taking into account the proximity to a plantation and the coherence between the plantation surface and the fumigation surface. Even so, some fumigation points are ruled out, either because there are no plantations near the points or because the distance to the closest newborns is greater than 5,000 meters.

2. The fumigation points are intersected with the fumigated plantations (both aerial and manual fumigation). Due to capacity limitations, this process is performed with the *Intersection* tool of Qgis. The result is a layer that contains all the alphanumeric information of the plantations and the fumigations. We then use the *Spatial Join* tool of ArcGis to move the result of the intersection to the plantations, joining the elements that share the space. This results in a layer containing the information of the number gallons of pesticides per hectare. We repeat this process for the unmatched points mentioned in step 1, in which each fumigation point is intersected with the municipality. Next, we execute the *Frequency* tool to get the sum of pesticides per municipality. Similarly, we calculate the frequency of total plantation' surface within each municipality. Both outputs are combined by using the *Spatial Join* tool in ArcGis, which offers a table with the average number of gallons of pesticides per hectares per municipality.

3. We use the previous results to create a new intersection with the results of pesticides applications and the plantation buffers. As a result, we obtain a new layer with the pesticides applied in each plantation in each buffer. Specifically, we obtain three measures: (1) area of each plantation in each buffer (square meters); (2) volume of pesticides (agrochemicals) for each plantation in each buffer (we multiply the area and the gallons per hectare of agrochemicals); (3) number of gallons with the mixed composition of pesticides for each plantation in each buffer (multiplying the area by the gallons per hectare of agrochemicals). We finally use the *Frequency* tool of ArcGis to obtain a table with the values of the newborn's ID, distance, and fumigation month, gallons of agrochemicals, and gallons of the mixed preparation.

Figure 2.C4 - Exposure to fumigated plantations

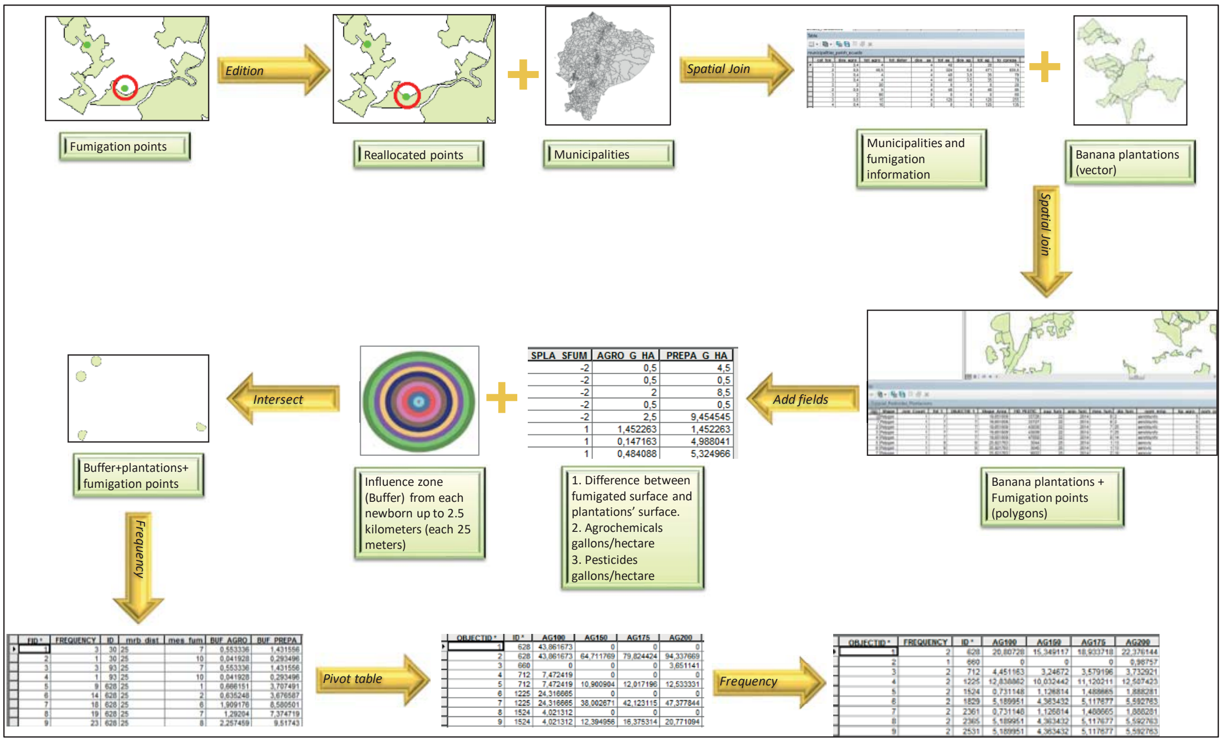


Figure 2.C5 - Exposure to fumigated plantations

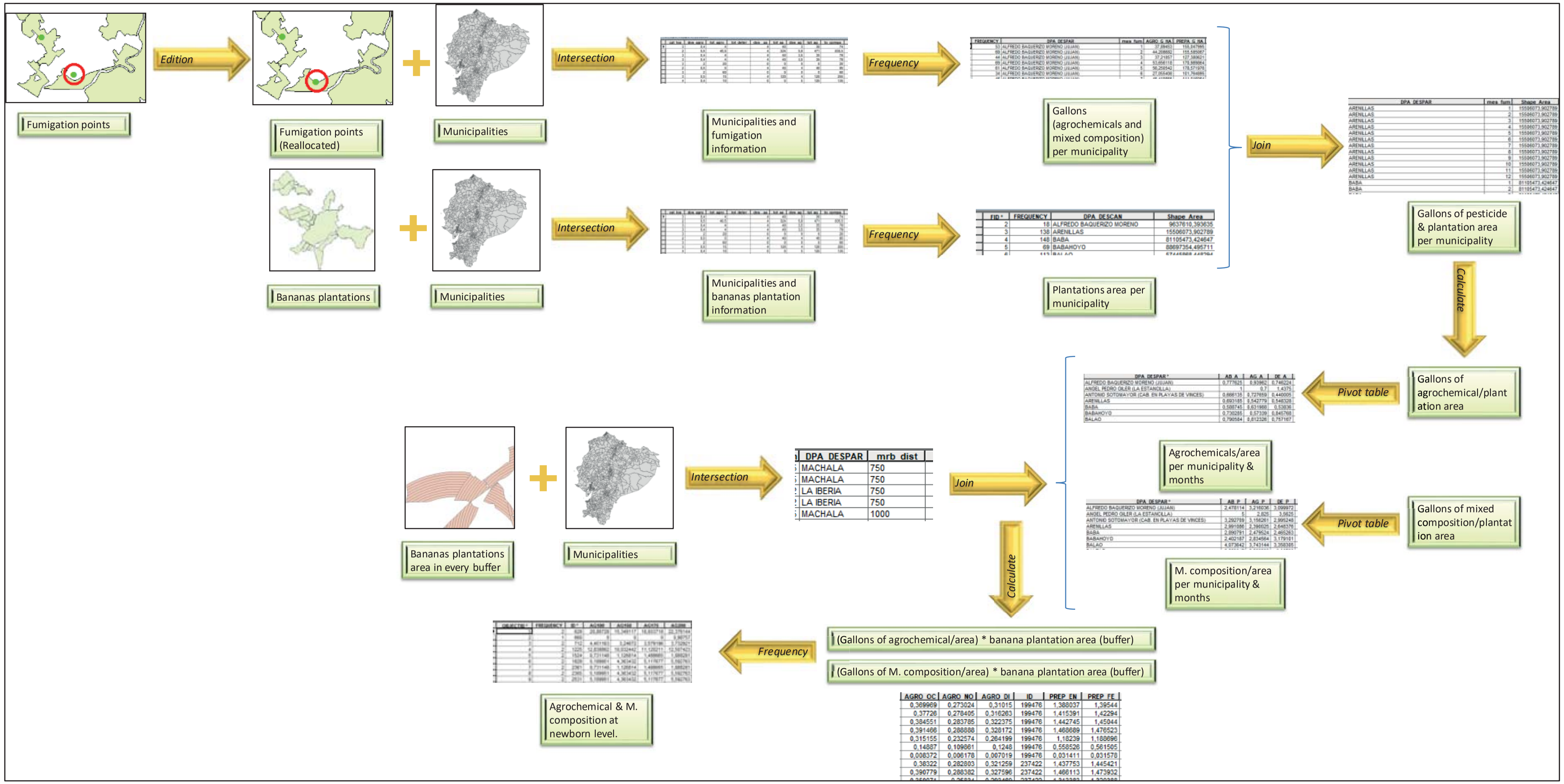
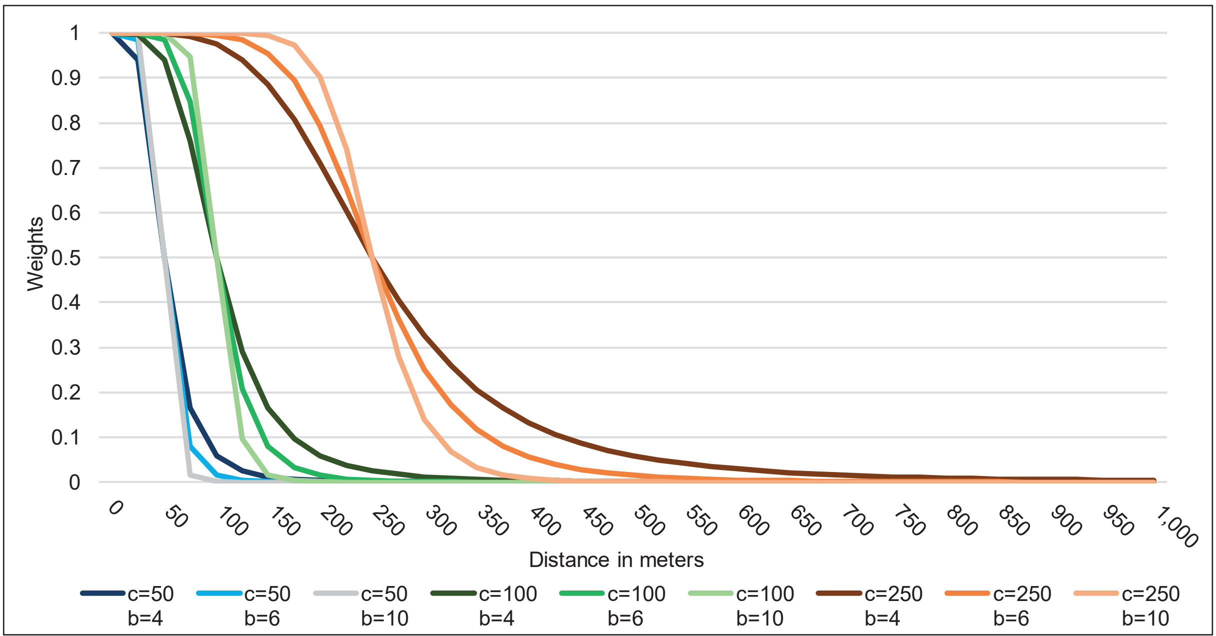


Figure 2.C6 - Decaying weight function



Note: The graphic illustrates the weight function in expression (1) for different values of the parameters *b* and *c*. For simplicity, we restrict the exposition to the first kilometer.

Appendix D – Auxiliary summary statistics and results

Table 2.D1 – Maternal characteristics by exposure to banana plantations and to other crops: Guayas province

Variable	Banana (1)	Rice (2)	Diff (3) (2) - (1)	Corn (4)	Diff (5) (4) - (1)	Cocoa (6)	Diff (7) (6) - (1)
Birth weight	3181.37	3039.42	-141.953***	3135.03	-46.348***	3131.97	-49.400***
	(11.31)	(9.84)	(14.964)	(9.46)	(14.644)	(13.66)	(17.882)
Apgar score 1 minute	7.93	8.05	0.115***	8.01	0.075***	7.91	-0.022
	(0.02)	(0.02)	(0.032)	(0.02)	(0.029)	(0.03)	(0.035)
Mother's age	24.22	25.16	0.935***	23.86	-0.357*	24.19	-0.031
	(0.14)	(0.12)	(0.185)	(0.13)	(0.189)	(0.17)	(0.224)
Male newborn	2.34	2.25	-0.092**	2.3	-0.046	2.22	-0.118**
	(0.03)	(0.02)	(0.039)	(0.03)	(0.043)	(0.04)	(0.050)
Female newborn	2.38	2.29	-0.086**	2.32	-0.058	2.24	-0.130***
	(0.03)	(0.02)	(0.040)	(0.03)	(0.043)	(0.04)	(0.050)
Mother's education Less than HS	5.82	6.43	0.610***	4.79	-1.029***	5.74	-0.084
	(0.05)	(0.04)	(0.064)	(0.05)	(0.065)	(0.07)	(0.079)
Mother's education HS or more	0.99	0.98	-0.004	0.99	0.003	0.99	0.004
	(0.00)	(0.00)	(0.004)	(0.00)	(0.003)	(0.00)	(0.004)
Local ethnic group "Montubio"	0.51	0.52	0.004	0.55	0.033**	0.53	0.019
	(0.01)	(0.01)	(0.014)	(0.01)	(0.014)	(0.01)	(0.017)
Mestizo	0.49	0.48	-0.004	0.45	-0.033**	0.47	-0.019
	(0.01)	(0.01)	(0.014)	(0.01)	(0.014)	(0.01)	(0.017)
Normal birth	0.48	0.44	-0.036***	0.49	0.016	0.46	-0.02
	(0.01)	(0.01)	(0.014)	(0.01)	(0.014)	(0.01)	(0.017)
C-Section birth	0.52	0.56	0.036***	0.51	-0.016	0.54	0.02
	(0.01)	(0.01)	(0.014)	(0.01)	(0.014)	(0.01)	(0.017)
Non marital union	0.01	0.06	0.052***	0.01	-0.001	0.02	0.009**
	(0.00)	(0.00)	(0.005)	(0.00)	(0.003)	(0.00)	(0.004)
Single	0.97	0.92	-0.050***	0.98	0.007	0.95	-0.019***
	(0.00)	(0.00)	(0.006)	(0.00)	(0.005)	(0.01)	(0.006)
Married	0.6	0.43	-0.168***	0.53	-0.075***	0.57	-0.034**
	(0.01)	(0.01)	(0.014)	(0.01)	(0.014)	(0.01)	(0.016)
Birth at a public hospital	0.4	0.57	0.168***	0.47	0.075***	0.43	0.034**
	(0.01)	(0.01)	(0.014)	(0.01)	(0.014)	(0.01)	(0.016)
Birth at a private hospital	0.37	0.31	-0.060***	0.3	-0.068***	0.36	-0.01
	(0.01)	(0.01)	(0.013)	(0.01)	(0.013)	(0.01)	(0.016)
Number of births	0.44	0.47	0.025*	0.51	0.065***	0.46	0.013
	(0.01)	(0.01)	(0.014)	(0.01)	(0.014)	(0.01)	(0.017)
Number of children	0.15	0.2	0.050***	0.15	0.001	0.15	0
	(0.01)	(0.01)	(0.010)	(0.01)	(0.010)	(0.01)	(0.012)
Prenatal control	0.92	0.81	-0.112***	0.89	-0.037***	0.84	-0.084***
	(0.01)	(0.01)	(0.009)	(0.01)	(0.008)	(0.01)	(0.010)
Single birth	0.08	0.19	0.112***	0.11	0.037***	0.16	0.084***
	(0.01)	(0.01)	(0.009)	(0.01)	(0.008)	(0.01)	(0.010)
Observations	2,319	2,968	5,287	2,598	4,917	1,475	3,794

Significance levels: * p<0.1 ** p<0.05 *** p<0.01. Standard errors in parentheses

Table 2.D2 – Maternal characteristics by exposure to banana plantations and to other crops: El Oro province

Variable	Banana (1)	Rice (2)	Diff (3) (2) - (1)	Cocoa (4)	Diff (5) (4) - (1)
Birth weight	3210.67	3231.58	20.907	3202.93	-7.741
	(26.69)	(160.56)	(119.116)	(28.98)	(39.538)
Apgar score 1 minute	8.24	7.95	-0.29	8.13	-0.105
	(0.06)	(0.14)	(0.236)	(0.07)	(0.087)
Mother's age	25.01	25.89	0.883	24.22	-0.787
	(0.36)	(1.42)	(1.576)	(0.39)	(0.534)
Male newborn	2.09	1.84	-0.243	2.1	0.018
	(0.07)	(0.23)	(0.285)	(0.08)	(0.101)
Female newborn	2.11	1.84	-0.272	2.14	0.022
	(0.07)	(0.23)	(0.294)	(0.08)	(0.104)
Mother's education Less than HS	6.65	7.47	0.826	6.11	-0.534***
	(0.12)	(0.60)	(0.536)	(0.13)	(0.178)
Mother's education HS or more	0.99	1	0.006	0.99	-0.001
	(0.00)	(0.00)	(0.018)	(0.01)	(0.007)
Local ethnic group "Montubio"	0.55	0.47	-0.078	0.53	-0.026
	(0.03)	(0.12)	(0.118)	(0.03)	(0.041)
Mestizo	0.45	0.53	0.078	0.47	0.026
	(0.03)	(0.12)	(0.118)	(0.03)	(0.041)
Normal birth	0.34	0.26	-0.08	0.39	0.05
	(0.03)	(0.10)	(0.112)	(0.03)	(0.039)
C-Section birth	0.66	0.74	0.08	0.61	-0.05
	(0.03)	(0.10)	(0.112)	(0.03)	(0.039)
Non marital union	0	0	-0.003	0	0.001
	(0.00)	(0.00)	(0.012)	(0.00)	(0.005)
Single	0.96	0.89	-0.061	0.97	0.011
	(0.01)	(0.07)	(0.050)	(0.01)	(0.016)
Married	0.45	0.32	-0.13	0.49	0.047
	(0.03)	(0.11)	(0.117)	(0.03)	(0.041)
Birth at a public hospital	0.55	0.68	0.13	0.51	-0.047
	(0.03)	(0.11)	(0.117)	(0.03)	(0.041)
Birth at a private hospital	0.45	0.32	-0.136	0.45	0.001
	(0.03)	(0.11)	(0.117)	(0.03)	(0.041)
Number of births	0.27	0.47	0.207*	0.36	0.090**
	(0.02)	(0.12)	(0.105)	(0.03)	(0.037)
Number of children	0.18	0.16	-0.027	0.16	-0.027
	(0.02)	(0.09)	(0.091)	(0.02)	(0.031)
Prenatal control	0.82	0.89	0.079	0.89	0.078***
	(0.02)	(0.07)	(0.091)	(0.02)	(0.029)
Single birth	0.18	0.11	-0.079	0.11	-0.078***
	(0.02)	(0.07)	(0.091)	(0.02)	(0.029)
Observations	341	19	360	272	613

Significance levels: * p<0.1 ** p<0.05 *** p<0.01. Standard errors in parentheses

Table 2.D3 – Maternal characteristics by exposure to banana plantations and to other crops: Los Rios province

Variable	Banana (1)	Rice (2)	Diff (3) (2) - (1)	Corn (4)	Diff (5) (4) - (1)	Cocoa (6)	Diff (7) (6) - (1)
Birth weight	3092.19	3095.35	3.155	3069.04	-23.147	3125.17	32.977*
	(12.66)	(19.35)	(22.840)	(13.61)	(18.571)	(12.11)	(17.519)
Apgar score 1 minute	7.8	7.7	-0.097**	7.78	-0.017	7.73	-0.070**
	(0.03)	(0.04)	(0.047)	(0.03)	(0.038)	(0.02)	(0.034)
Mother's age	23.91	23.91	0.005	23.89	-0.02	24.1	0.189
	(0.17)	(0.24)	(0.296)	(0.17)	(0.240)	(0.16)	(0.230)
Male newborn	2.26	2.2	-0.058	2.14	-0.121**	2.25	-0.009
	(0.04)	(0.05)	(0.063)	(0.04)	(0.051)	(0.04)	(0.050)
Female newborn	2.29	2.22	-0.067	2.17	-0.124**	2.28	-0.007
	(0.04)	(0.05)	(0.064)	(0.04)	(0.052)	(0.04)	(0.052)
Mother's education Less than HS	5.84	6.24	0.402***	6.05	0.206***	5.93	0.091
	(0.05)	(0.07)	(0.095)	(0.05)	(0.076)	(0.06)	(0.078)
Mother's education HS or more	0.99	0.99	0.001	0.99	0.004	0.99	0
	(0.00)	(0.00)	(0.005)	(0.00)	(0.004)	(0.00)	(0.004)
Local ethnic group "Montubio"	0.53	0.51	-0.016	0.52	-0.01	0.5	-0.02
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
Mestizo	0.47	0.49	0.016	0.48	0.01	0.5	0.02
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
Normal birth	0.49	0.38	-0.106***	0.45	-0.037**	0.49	0.005
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
C-Section birth	0.51	0.62	0.106***	0.55	0.037**	0.51	-0.005
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
Non marital union	0.01	0.04	0.036***	0.03	0.026***	0.04	0.032***
	(0.00)	(0.01)	(0.006)	(0.00)	(0.005)	(0.00)	(0.005)
Single	0.97	0.95	-0.020**	0.95	-0.017**	0.94	-0.025***
	(0.00)	(0.01)	(0.009)	(0.01)	(0.007)	(0.01)	(0.007)
Married	0.51	0.43	-0.080***	0.5	-0.012	0.51	0.004
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
Birth at a public hospital	0.49	0.57	0.080***	0.5	0.012	0.49	-0.004
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
Birth at a private hospital	0.47	0.44	-0.031	0.48	0.015	0.43	-0.043**
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
Number of births	0.39	0.42	0.039*	0.39	0.008	0.45	0.070***
	(0.01)	(0.02)	(0.022)	(0.01)	(0.018)	(0.01)	(0.017)
Number of children	0.11	0.11	-0.003	0.1	-0.012	0.09	-0.023**
	(0.01)	(0.01)	(0.014)	(0.01)	(0.011)	(0.01)	(0.010)
Prenatal control	0.77	0.82	0.046**	0.79	0.017	0.77	0
	(0.01)	(0.01)	(0.018)	(0.01)	(0.015)	(0.01)	(0.014)
Single birth	0.23	0.18	-0.046**	0.21	-0.017	0.23	0
	(0.01)	(0.01)	(0.018)	(0.01)	(0.015)	(0.01)	(0.014)
Observations	1,607	736	2,343	1,444	3,051	1,757	3,364

Significance levels: * p<0.1 ** p<0.05 *** p<0.01. Standard errors in parentheses

Table 2.D4 – Effects of pesticides exposure on newborn girls birth weight: whole sample and normal birth

	Girls – Buffer 2.5 Km				Girls – normal birth – Buffer 2.5 Km			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure buffers	-0.0006*	-0.0011*	-0.0034*	-0.0061**	-0.0014**	-0.0023**	-0.0071**	-0.0129**
	(0.0004)	(0.0006)	(0.0017)	(0.0028)	(0.0007)	(0.0010)	(0.0030)	(0.0051)
Mother's Controls	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	24,247	24,247	24,247	24,247	12,028	12,028	12,028	12,028
R2	0.1011	0.1011	0.1011	0.1011	0.1060	0.1061	0.1061	0.1062

Notes: Each coefficient corresponds to the result of a different estimation of equation (2), where the dependent variable is the newborns' birth weight. The left panel shows the results with the whole sample of newborn girls and the right panel with newborn girls that had a normal birth. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. *Exposure Buffer* is a continuous variable that considers the sum of the 100 weighted buffers with the square meters of the plantations close the mothers' residences. The table shows results for different values of the parameters *b* and *c* for the weighting function in expression (1). The controls of child characteristics are indicators of single birth. The controls of the maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorians, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 128 in the left panel, and 112 in the right panel, excluding singleton observations. The reported R–squared is the same for all the coefficients in each column. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.D5 – Effects of pesticides exposure on newborn boys birth weight: whole sample and normal birth

	Boys – Buffer 2.5 Km				Boys – normal birth – Buffer 2.5 Km			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure buffers	-0.0005	-0.0009	-0.0027	-0.0045	-0.0011**	-0.0018**	-0.0055**	-0.0099**
	(0.0004)	(0.0007)	(0.0021)	(0.0035)	(0.0005)	(0.0008)	(0.0024)	(0.0040)
Mother's Controls	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	25,777	25,777	25,777	25,777	12,449	12,449	12,449	12,449
R2	0.0836	0.0836	0.0836	0.0836	0.0928	0.0929	0.0929	0.0929

Notes: Each coefficient corresponds to the result of a different estimation of equation (2), where the dependent variable is the newborns' birth weight. The left panel shows the results with the whole sample of newborn boys and the right panel with the newborn boys that had a normal birth. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. *Exposure Buffer* is a continuous variable that considers the sum of the 100 weighted buffers with the square meters of the plantations close the mothers' residences. The table shows results for different values of the parameters *b* and *c* for the weighting function in expression (1). The controls of child characteristics are indicators of single birth. The controls of the maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorians, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 127 in the left panel, and 116 in the right panel, excluding singleton observations. The reported R–squared is the same for all the coefficients in each column. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.D6 – Effects of pesticides exposure on newborns' birth weight: mothers' education level

	Less educated mothers – Buffer 2.5 Km				More educated mothers – Buffer 2.5 Km			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure buffers	-0.0012**	-0.0019***	-0.0060***	-0.0106***	0.0001	0.0001	0.0004	0.0009
	(0.0005)	(0.0007)	(0.0022)	(0.0037)	(0.0004)	(0.0006)	(0.0017)	(0.0027)
Mother's Controls	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	19,403	19,403	19,403	19,403	30,619	30,619	30,619	30,619
R2	0.1071	0.1071	0.1071	0.1071	0.1000	0.1000	0.1000	0.1000

Notes: Each coefficient corresponds to the result of a different estimation of equation (2), where the dependent variable is the newborns' birth weight. The left panel shows the results with newborns from less educated mothers and the right panel with more educated mothers. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. *Exposure Buffer* is a continuous variable that considers the sum of the 100 weighted buffers with the square meters of the plantations close the mothers' residences. The table shows results for different values of the parameters *b* and *c* for the weighting function in expression (1). The controls of child characteristics are indicators of single birth and sex. The controls of the maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorians, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 121 in the left panel, and 131 in the right panel, excluding singleton observations. The reported R–squared is the same for all the coefficients in each column. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 2.D7 – Effects of pesticides exposure on newborn girl birth weight: mothers' education level

	Girls - Less educated mothers – Buffer 2.5 Km				Boys - Less educated mothers – Buffer 2.5 Km			
	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15	c=100, b=4	c=100, b=15	c=50, b=4	c=50, b=15
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exposure buffers	-0.002***	-0.003***	-0.0090***	-0.0150***	-0.0005	-0.0011	-0.0032	-0.0066
	(0.0006)	(0.0010)	(0.0028)	(0.0047)	(0.0008)	(0.0012)	(0.0037)	(0.0062)
Mother's Controls	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	9,411	9,411	9,411	9,411	9,986	9,986	9,986	9,986
R2	0.1180	0.1179	0.1180	0.1180	0.0929	0.0930	0.0930	0.0930

Notes: Each coefficient corresponds to the result of a different estimation of equation (2), where the dependent variable is the newborn girls birth weight. The left panel shows the results for newborn girls from less educated mothers and the right panel from more educated mothers. The sample is limited to births by mothers living up to 2.5 kilometers from the plantations. *Exposure Buffer* is a continuous variable that considers the sum of the 100 weighted buffers with the square meters of the plantations close the mothers' residences. The table shows results for different values of the parameters *b* and *c* for the weighting function in expression (1). The controls of child characteristics are indicators of single birth. The controls of the maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (mestizo, montubio, white, afroecuadorians, indigenous, other), dummy indicator of place of birth (public or private hospital), indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number is 116 in the left panel, and 115 in the right panel, excluding singleton observations. The reported R–squared is the same for all the coefficients in each column. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

3 Chapter 3 – Femicides: laws, women empowerment, and retaliation effects

3.1 Introduction

Gender violence and female homicides have been declared as a public health matter and represent a violation of women's human rights (World Health Organization, 2018). The mitigation of violence against women is one of the United Nations sustainable development goals (United Nations, 2015). However, eradication of violence against women faces socio-cultural challenges including gender inequalities, male rejection against women empowerment, and weak justice efforts to solve gender-violence crimes. Indeed, nearly 34% of intentionally killed women around the world have been reported as been intentionally killed by their intimate partner, but a big share of them are unsolved cases and not sentenced as femicides (World Health Organization, 2018; UNODC, 2018). [24]

Female homicides and gender-violence have been associated with gender inequalities, women's access to resources including subsidies and wages, and also emotional dependence to their partner (Bart and Moran, 1993). There are also studies showing that social interventions to decrease gender gaps through employment and education may lead to reduce levels of gender-violence and intra-partner homicides rates (Dugan et al., 2003; Dawson et al., 2009; Eriksson and Mazerolle, 2013). In spite of this, there are studies showing that gender equality policies may adversely lead to high levels of domestic violence due to male/female stigma and social norms, and marital conflicts as a response against women empowerment (Dugan et al., 2003; Angelucci, 2008; Xie et al., 2012). Some papers show that gender violence can emerge after the introduction of legislative changes to promote gender equality and to penalize violence against women (Angelucci, 2008; Banerjee, La Ferrara, and Orozco, 2019). This problem is known as the retaliation effect, or backlash effect. The objective of this paper is to analyze whether women empowerment and the toughening of the laws on femicides in Ecuador in 2014 gave rise to a retaliation effect that temporary increased female homicides.

[24] Several papers have examined the consequences of crime and intra-household violence. Childhood adverse experiences on chaotic homes generate delinquency in the adulthood (DeLisi et al., 2017; Bonner et al., 2019). It also prompts antisocial behavior which may turn into arrests, incarceration, or probation (Beaver et al., 2015).

Crime in Ecuador has gradually decreased during the last decades, from 18 homicides per 100 thousand inhabitants in 2008, to nearly a rate of 6.1 in 2020. This reduction in the number of cases responds to the increase in the control to street violence, organized crime, and domestic violence (ECLAC, 2015; Larrea, 2018; INEC, 2020; UNODC). However, violence against women is a latent problem in this country, where one female homicide is reported each 2 to 3 days. More specifically, there is an average of 2.85 victims per 100 thousand inhabitants for the period 2010-20. More recently, it has been reported that nearly 40 cases of violence against women were attended in average in each Judicial Units of the country (nearly 2,500 cases) during the confinement period in Ecuador (March- May 2020). Most of the victims were single women aged between 15 to 34 years old, and among 60% of these had at least one child left to orphanhood. Another relevant characteristic of the victims is that nearly 70% of them were students or housewife. Whereas the perpetrators are aged between 25 to 39 years old, who had or still have a sentimental relationship with the victims at the moment the female homicide was committed. Nearly the 75% of the female homicides were committed with light-weapon or choke.

The severity of this problem led the government of Ecuador to introduce the *femicide* penalty type in the reform of the penal code, approved in 2014. This homicide type increased the number of prison years to up to 34 for gender-violence perpetrators, with the objective of reducing violence against women. Before this, female homicides were considered as *homicide* or *assassination*, which implied that the perpetrator faced lesser years of prison.

One important aspect of the new legislation is that it has not been enforced homogenously across all municipalities. Specifically, after the introduction of the *femicide* type of penalty in the 2014 penal code, similar gender-violence victims were classified as *femicide* in some municipalities, and as *homicide* or *assassination* in other municipalities. This difference in the classification of gender-violence crimes can be due to lack of criteria or training of judiciary authorities on the female homicides subject[25], or in some case to the lack of effort on solving femicide cases. This later situation is known as *impunity* and implies that the perpetrator of a crime does not receive an accurate sentence, reflecting socio-cultural norms that undermines the gender-violence (*Fiscalia General del Estado*, 2019). Moreover, some municipalities that

[25] The literature has documented differences in criteria to determine gender violence risk factors, and criminal characteristics associated to female homicides (Bugeja et al., 2013; Sarmiento et al., 2014). In their review, jurisdictions from Australia, United Kingdom and the United States differ on the examination of a domestic or family violence death. According to this review, the associated factors to female homicides are the prior homicide threats, whether there is dominant behavior against victims' activities, access to gun or other weapon and alcohol and drug abuse (Garcia et al., 2007; Bugeja et al., 2013; Stefanska et al., 2017; Sorrentino et al., 2020; Graham et al., 2019; Johnson et al., 2020). Despite these studies, there is an important debate on the definition and measure of femicides (Dawson and Carrigan, 2020).

continued using *homicide* and *assassination* eventually enforced the term *femicide* to record gender-violence victims. Therefore, I exploit the temporal variation in the enforcement of the *femicide* type of penalty to identify its association on the rates of femicides.

In addition to the reform of the penal code, the Ecuadorian government has introduced several measures to increase women empowerment, which affect women's working conditions, participation in politics, or which consisted in offering cash transfers to increase the women's financial independence (Zeoli and Webster, 2010; Hidrobo and Fernald, 2013; Bulte and Lensink, 2019).

This paper studies how the reform of the Ecuadorian penal code in 2014 and the increase of women empowerment has affected female homicide rates. To my knowledge, this is the first paper to analyze the existence of a retaliation effect as a result of a modification of the legislation on gender-violence for a developing country. In order to do so, I consider information on the homicides' events coming from the national homicides register of Ecuador gathered by the *Ministerio del Interior*. I consider the period 2010-2020, which is the period for which the homicides' geographical occurrence is available. The dataset I use includes information for nearly 14,000 homicides across the whole country during the period 2010-20. The 15.5% (N=2,167) of these cases were female homicides, with an average age of 34 years old, and more than the 50% of them were single women. Gender-violence victims (femicides) represent the 80% of female homicides (N=1,711). In my analysis I use this information to identify the groups of municipalities that enforced the *femicide* penalty type, and those that did not, when a gender-violence female homicide occurred. In addition, I use two victimization surveys for the years 2011 and 2019 to identify the evolution of women empowerment at the municipality level. Specifically, I use these surveys to compare the share of women who agree or disagree on statements in favor of male dominance versus women empowerment.

The first contribution of my analysis is to provide insights on the evolution of female homicides in Ecuador in the period 2010-20. I split the analysis in 4-year periods to compare the situation before the introduction of the new penal code in 2014 (2010-2013), the 4-year period after the approval of the new code (2014-2017), and the three last years (2018-2020) since in 2018 the Ecuadorian government approved a new legislation to prevent violence against women. My analysis shows that in the period 2010-20, almost 80% of all female homicides constituted gender violence, and almost 60% of them took place in the victim's house or in other non-public places. Moreover, the proportion of gender-violence victims increase from 75% before the new penal code, to 83% after its approval, relative to the number of victims from other type of violence (including robbery and drug trafficking). I also explain that female homicide rates and gender-violence rates have decreased from 2010 to 2020. However, I observe different trends before and after the new penal code approval in 2014. Indeed, after 2014 some municipalities that adopted and enforced the use of *femicide* eventually show higher female homicide and gender-violence rates than the municipalities that did not. These results are in line with the findings of previous analysis (Ministerio del Gobierno, 2019; Pontón et al. 2020). In this sense, Fernandez (2017) and Larrea (2018) study the judicial response of the new code by comparing female homicide before and after the legislative reform. They also report that high rates of female homicides are not contemplated as femicides.

I also show the evolution of female homicide rates, considering the variation in the levels of women empowerment at the municipality level. In the municipalities that did not adopt the *femicide* penalty type, female homicide rates decreased from 4.3 to 2.81 victims per 100 thousand inhabitants, from the periods 2010-13 to 2014-17. By contrast, in municipalities that adopted the new code, the female homicide rate increased in the same period from 2.18 to 2.85 victims per 100 thousand inhabitants. Considering women empowerment, I explain that female homicides rates increased from 1.89 to 2.03, from the periods 2010-13 to 2014-17, in the municipalities that have seen an increase of women empowerment. By contrast, in municipalities with no increase in women empowerment, female homicide rates decreased in the same period from 2.8 to 1.35 victims per 100 thousand inhabitants.

The second contribution of the paper is to provide empirical evidence that the 2014 reform of the penal code generated a retaliation effect that increased the number of femicides. For this, I exploit the temporal difference in the enforcement of the *femicide* penalty type, and I account for differences on women empowerment at the municipality level. The results from the empirical estimation show a positive association between the enforcement of the *femicide* penalty type and the increase in the number of female homicides. The results suggest that the municipalities that enforced the *femicide* type of penalty experienced an 0.97 SD increase in the female homicide rates, relative to those municipalities that registered gender-violence victims, but that did not enforce the use of *femicide* penalty type. In addition, I find that enforcement of *femicide* classification is associated with a 0.28 SD increase in the female homicide rate, in municipalities that exhibits an increased level of women empowerment.

Overall, the results show that the penalization of female homicides, as a policy to protect women by setting highest punishment to the perpetrators, might have temporarily created a retaliation effect, in the context of Ecuador. Interesting enough, these results are in line with previous evidence of the retaliation effect against gender equality policies, and interventions against domestic and gender violence (Angelucci, 2008; Banerjee, La Ferrara and Orozco, 2019). These findings appeal for interventions addressed to circumvent a retaliation against the penalization of violence against women. Moreover, public policy should prevent future violence and not only penalize the committed crimes.

The remainder of this paper is organized as follows. Section 2 presents a revision of the literature. Section 3 describes which has been the evolution of crime in Ecuador in the last years and explains the reform of the penal code. Section 4 describes the data used in this analysis and describes the empirical strategy. Section 5 shows and discusses the results. Finally, Section 6 summarizes the main findings of the research.

3.2 Literature review

This work builds on and contributes to the literature that studies domestic and gender-violence, and the adverse effects of regulations targeted to increase women's protection and empowerment. Female homicides are a consequence of gender inequality, males' response against women's access to resources, and emotional dependence to their partner (Bart and Moran, 1993). The literature uses two different approaches to explain victimization. First, some studies consider that violence against women is related to gender inequality. They show that in patriarchal societies where the social status of women is very low relative to men, the community may consider gender violence as acceptable (Whaley and Messner, 2002; Xie et al., 2012). In line with this idea, some authors suggest that policies oriented to reduce the time shared between the women and her violent partner, such as divorce, employment, or education, will derive in the reduction of violence between them (Dugan et al., 2003). This approach implies that gender equality can be a channel to reduce dependence and tights on their male partner, and women may avoid or drop violent relationships (Dawson et al., 2009), and consequently the reduction on intra-partner homicides rates perpetrated by the male partner (Eriksson and Mazerolle, 2013).

The second approach adopted by the literature, which can be complementary to the previous one, considers that gender violence can be a reaction to the policies and behaviors seeking to increase gender equality. Some studies have described the existence of a retaliation effect, by which male partner recognizes the loss of authority or control over their female partner (Dugan et al., 2003). In this context, spousal violence may be a "bargaining instrument", adopted by the husband to impose his control (Anderson, 1997; Johnson and Ferraro, 2000; Angelucci, 2008). Some authors argue that the wish to introduce quick social changes through legislative reforms may generate important cost due to household's beliefs on males' dominance, leading to more marital conflicts and domestic violence (Sunstein, 1996; Xie et al., 2012, Wheaton, 2021).

The economic literature is increasingly studying the effects of policy interventions on gender equality and gender-violence. On one hand, recent studies analyzed that violence against women can be reduced through cash transfers (Hidrobo and Fernald, 2013; Gibbs et al., 2020). In particular, Hidrobo and Fernald (2013) finds that the financial alleviation of the household through subsidies leads to a reduction on marital conflicts. On the other hand, some policies such as the education and women social inclusion can be used to reduce violence. In spite of this, there is the concern that policy interventions on equality could worsen violence due to strong social norms and adverse reactions against empowerment (Vyas and Watts, 2009; Banerjee, La Ferrara, and Orozco, 2019; Bulte and Lensink, 2019; Gibbs et al., 2020).

A growing body of literature addresses the consequences of public policy on violence against women. For instance, the economic research has shown that intra-partner violence, gender violence, and murder of women are affected by cash transfers (Hidrobo and Fernald, 2013), war and armed conflicts (Diaz, Salas and Tribin, 2020), female police officers (Miller and Segal, 2019), domestic violence policies, alcohol taxes and police staffing levels (Zeoli and Webster, 2010), and in forced coexistence during the recent pandemic lockdown (Arenas-Arrollo et al., 2020).

Other stream of economic literature has shown that violence against women can be explained through divorce and other mechanisms that increase women empowerment and reduce men bargaining power. Divorce represents an outside option for women, and it may generate spousal violence, as the male partners' last resource to state his dominance (Eswaran and Malhotra, 2011). On the other hand, divorce plays a role as promoting women empowerment, economic independence or reducing stigma of breaking the marriage, which derives in less benign outcomes (Cruz and Henderson, 2017). Also, there is evidence that some policies have generated a retaliation effect that entail a more intense level of abuse (Bulte and Lensink, 2019 and 2020). This situation is in general explained with the idea that the effectiveness of new legislations and policies are in general affected by social norms and attitudes (Acemoglu and Jackson, 2017).

3.3 Gender-violence in Ecuador

This section explains the main legislative changes introduced in Ecuador in the last years to reduce gender-related violence. Then, I describe the evolution of femicides in the period 2010-2020, focusing on the differences across municipalities.

3.3.1 Reform of the Penal Code

Female homicides are a latent problem in Ecuador. Despite the government efforts to reduce domestic violence with the 2007 National Plan to Reduce Gender-Violence, and the creation in 2013 of judiciary units specialized on domestic-violence, the rate of female homicide increased from 2.85 in 2010 to 3.2 by 2017, and it remained at 2.63 in 2019 (INEC, 2020). In the period 2010-2020, it has been reported nearly three female homicides per week (DINASED, 2020). Moreover, female homicides have affected nearly the 50% of all Ecuadorian municipalities, with a higher presence in the coastal and the Andean region (INEC, 2020). As an illustration, during the pandemic confinement period (March-May 2020) almost 2,500 cases of violence against women were reported in Ecuador, and there were 18 female homicides were reported in the same period, including the homicides of teenagers and young women. Importantly, during 2020 less than 50% of female homicides were solved by the local judicial authorities. [26]

During the last decades, Ecuadorian governments have passed several laws and strategic plans to stop the violence and killing of women. The laws to control violence against women began to develop in 1995 following the *Belém do Pará* convention.[27] The objective of this law was to legally set actions and punishment against women aggression. Later in 2007, the Ecuadorian government released the *Plan Nacional del Buen Vivir* (PNBV) and the *Plan Nacional de Erradicación de la Violencia de Género* (PNEVG), which served as a political agenda to fight violence against women, to provide standards to identify and anticipate gender-violence victims, and also to provide priorities in the government bodies' agenda towards women victimization. The purpose of these initiatives was to set a political agenda and objectives in the short and long run. Despite these efforts, many female homicides cases were not punished as such due to legal gaps, ambiguous legal definitions, or definitions open to criteria of the authorities.

The Ecuadorian penal code of 1971 lacked a legal classification of "*femicide*", a situation that was not corrected until 2013. In the year 2014, the Ecuadorian government passed the new penal code (COIP) that among other things introduced several aspects of crime against women that were not contemplated previously code, such as harassment, digital felonies, gender violence and hate crimes. More importantly, the COIP defines

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[26] Local newspapers also report some disparities in the cases that the General Attorney Offices solve and the cases the local organizations and security offices report. See https://www.planv.com.ec/historias/sociedad/el-feriado-mas-violento-contra-mujeres.

[27] Law against violence to the women and the family, approved the 29th of November 1995 and released in Official Registry No. 839 the 11th of December 1995. This law follows the Inter-American Convention on the Prevention, Punishment, and Eradication of Violence against Women (Convention of *Belém do Pará*), in which Ecuador signed on 10th January 1995.

a *femicide* as a type of homicide, and it describes the conditions in which a female homicide should be considered as a femicide or as an assassination or a homicide.[28] One of the most important changes of the new penal code is that the perpetrators of a *femicide* can be punished between 22 to 34 years of incarceration, considering that these types of homicides are against the women's gender. However, some cases that ought to be classified as *femicides* can be determined as an *assassination* or *homicide* if the General Attorney is not able to stablish a victim-perpetrator relationship. Indeed, after the introduction of the femicide type of penalty in 2014, some gender-violence victims were classified as *femicide* in some municipalities, and some other gender-violence victims with the same reason of committing the crime, were classified as *homicide* or *assassination* in other municipalities. The specific categorization of a crime as a *homicide* or a *femicide* is stablished by the judges based on the information of the victim, the perpetrator, and the death circumstances. However, many female homicides are left to impunity, due to the impossibility or to the lack of efforts to have enough evidence on the homicide circumstances, leaving the perpetrator without a sentence, as explained by Carcedo (2011), Camacho (2014), Fernandez (2017), and Larrea (2018).

In 2013, the National Judiciary Council created the *Unidades Judiciales* to examine the denounces of violence against women and family members, and to address judiciary response to protect the gender-violence victims. The number of judiciary dependences increased to 226 by 2018, of which nearly 70 offices were re-structured to put in practice legal and social protocols.

More recently, on the 5th of February 2018, the Ecuadorian government released the Organic Integral Law to Prevent and Eradicate Violence Against women. The objective of this law is to nudge social and civil organizations to strength their functions, to identify potential existence of gender-violence, and to increase their services and duties in favor of the women. In spite of this, the law did not address the problem of the existence of impunity cases.

3.3.2 Femicides in Ecuador

This section characterizes the female homicides that took place in Ecuador in the period 2010-2020. For this analysis, it is important to clarify that the decision to classify a homicide as a femicide corresponds to the General State Attorney (*Fiscalia General del Estado*). According to the National Directorate of Investigation of Crimes Against Life (DINASED), this decision has to be based on the information on the relationship between victim and perpetrator. Moreover, femicides can correspond to the following cases of gender-violence: acts of hate, threats, financial debt and assets disputes,

[28] In fact, the decision on femicide penal type is based on the Article 141 of the COIP jointly with the proofs and pre-administrative research on the victims' death conditions.

emotional and sentimental violence, fights, harassment, and sexual violation (DINASED, 2020; *Fiscalia General del Estado*, 2020).

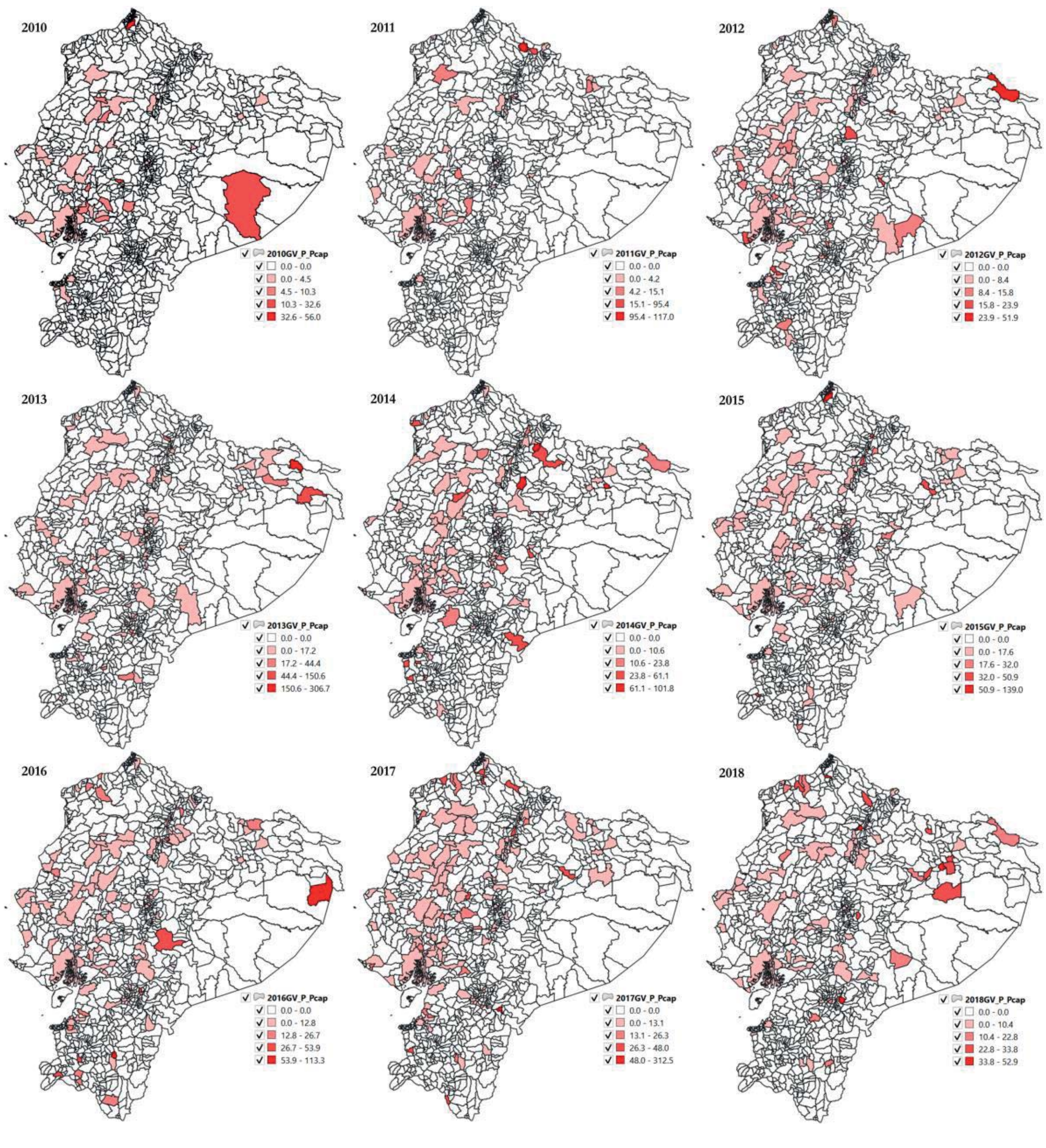
Information on the homicides events comes from the national homicides register of Ecuador gathered by the *Ministerio del Interior*. I use the information from the years 2010 to 2020, which is the period for which the homicides' geographical occurrence is available. The data includes information for nearly 14,000 homicides across the whole country during the period 2010-20. From these, about the 15.5% (N=2,167) corresponds to female homicides. Femicides (gender-violence homicides) represent the 80% of this number (N=1,711). Figure 3.1 illustrates the geographic distribution of femicides per 100,000 inhabitants in Ecuador during the years 2010 to 2018. Femicides have been concentrated in the coastal side of the country, which concentrates most of the country population. In the period I analyze the cities Guayaquil and Quito accounted for almost the 25% of total female homicides. These two cities have adopted several policies and measures to increase security, mitigate domestic violence, and to provide psychological help for victims who suffered gender-violence directly or indirectly (Ministerio del Gobierno, 2019; Pontón et al. 2020).

Table 3.1 presents the socio-economic characteristics of the victims of the female homicides. For this, I consider three different periods: (1) 2010-2013, before the 2014 reform of the penal code; (2) 2014-2017, between the 2014 reform of the penal code and the 2018 Law to Prevent and Eradicate Violence Against Women; and (3) 2018-2020, after the 2018 Law to Prevent and Eradicate Violence Against Women. Before the 2014 reform of the penal code, female homicides by gender-violence were classified as homicides or assassination.

The first relevant result of this table is that in the period examined there was a decrease in the number of female homicides. Despite this, the Table 3.1 shows an increase in the proportion of gender-violence crimes relative to other types of violence, such as robberies and drug trafficking. This can be visualized in Figure 3.2, which presents the yearly number of female homicides, between gender-violence victims and other-violence victims. Specifically, I find that before 2014 nearly the 75% of the cases were reported to be gender-related homicides, and this percentage increased to 83% after the approval of the new penal code.

When I consider the penalty type, I observe that *femicide* classification started to be enforced from 2014, since the previous penal code did not penalize gender-violence. However, I observe that in the period 2014-17 following the reform of the penal code, only 33% of female homicides were considered as *femicides*, while the percentage of gender-violence victims represented the 83% of total female homicides cases. This percentage shows that the *femicide* penalty type was not enforced in all the gender-violence homicides, which can be due to the lack of criteria to apply this type, or to the lack of resources/efforts to solve such crimes. Notice that for the last period 2018-20, the proportion *femicide* cases raised to 44%, while the gender-violence victims decreased to 81%, which may reflect more efforts to enforce the *femicide* classification.

Figure 3.1 – Femicides per 100,000 inhabitants in Ecuador (2010-2018).

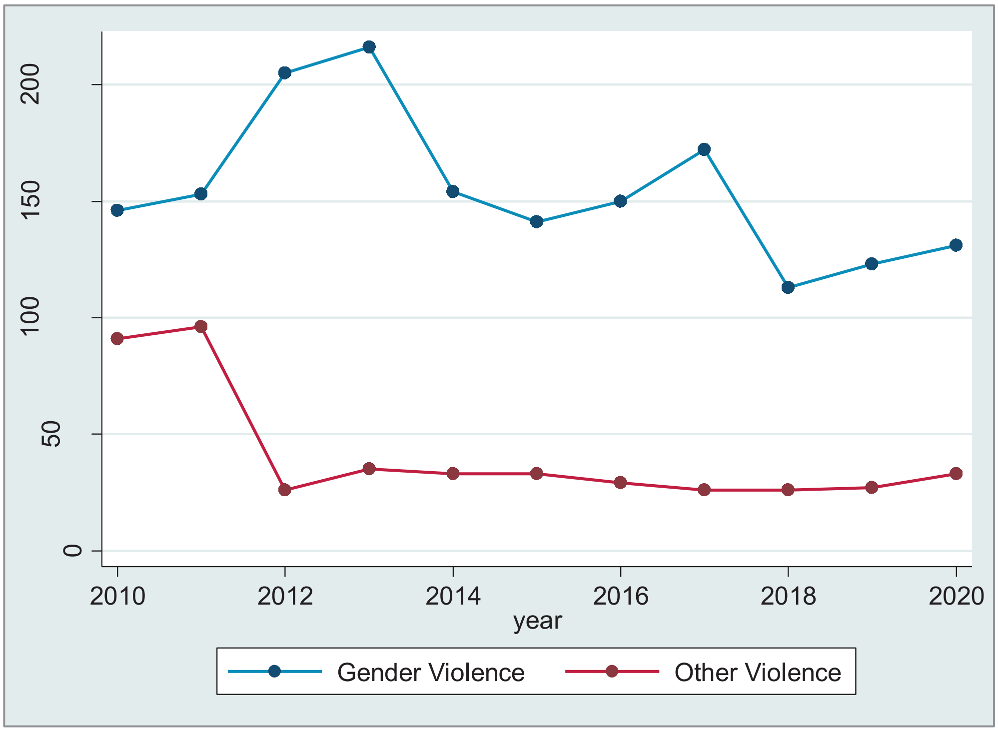


Note: The legends show the year and the values of the femicides per capita.
Source: Author's elaboration. Data from the homicides' register.

The increase in the number of gender-violence homicides from the period 2010-13 to 2014-17 can be related to two situations. First, to better efforts to of the victims considering the circumstances of their death. And second, to an increase in the number of cases as a result of a retaliation effect. Indeed, the new law supposes an increase in the women's empowerment, as it enforces the use of the *femicide* type of penalty, to better protect women and mitigate gender-violence homicides. In the section 4 of this paper, I examine this hypothesis in more detail.

The information collected also shows that the proportion of female homicides that took place in a private place increased from 46% in the period 2010-13 to 68% in the period 2018-20, which can reflect a larger percentage of domestic violence relative to other types of violence. I also observe that in the three periods considered, the average age of the female victims was 33 to 34 years old, more than 50% where single women (there is an increase in the percentage of non-married victims), and around 60% of homicides occurred in urban areas.

Figure 3.2 – Yearly evolution of female homicides by type of violence, from 2010 to 2020



Source: Author's elaboration. Data from the homicides' register.

Table 3.2 compares the characteristics of gender-violence victims relative to the victims of other types of violence. Some relevant differences among the victims are the age, marital status, education, and the place in which the homicide was committed. On average, age is much lower for gender-violence victims than for the victims of other types of crime. Due to this low age, most gender-violence victims were single. Regarding victims' education, we obtain that those victims in both groups had basic to secondary education. Finally, in accordance with the literature on gender-violence homicides, it is shown that around 60% of the female victims suffered violence at home, hotels, or other private places, while almost 50% of the other-violence homicides occurred at private places.

3.4 Empirical analysis of the retaliation effect

This section examines the hypothesis that the reform of the Ecuadorian penal code in 2014 could generate a retaliation effect that increased the number of gender-related victims. Next, I explain the data and the empirical strategy used in the analysis, and in the next section I present the main results.

3.4.1 The data

My analysis uses the homicides data gathered by the Ministry of Interior, which includes information of the violent death victims' characteristics, the sex, the reason of the death, and geographical information of the municipality of occurrence. I aggregate the number of female homicide victims at the municipality level to obtain the $Female\ Homicide\ Rate_{mt}$, a variable that computes the total number of female homicides per 100 thousand inhabitants in municipality m and in year t. I also compute the $Gender\ Violence\ Rate_{mt}$ variable, which considers the total number of gender-violence victims per 100 thousand inhabitants. Table 3.3 shows that female homicide rates have decreased along the period 2010-2020, which is line with the general trend of a reduction of gender-violence homicides observed in Table 3.1. The reduction in the female homicides rates can partly reflect the ongoing government efforts to fight crime and reduce domestic violence. However, it is important to have in mind the heterogeneity in the application of the new penal code across municipalities.

In Ecuador, local authorities and media has claimed that after 2014 there has been weak justice efforts to determine whether a female homicide should be classified as *femicide* or not (Carcedo, 2011; Camacho, 2014; Fernandez, 2017; Larrea, 2018).[29] In the homicides register, it is possible to identify in which municipalities there was at least one female homicide classified as a *femicide* after 2014, and which municipalities did not apply this penalty type. I use this information to create the variable $Enforcement_{mt}$, which shows in which year the municipality's judiciary authorities started to use the *femicide* penalty type.

Table 3.4 replicates Table 3.3 but splitting the analysis between municipalities that used or not the *femicide* penalty type after 2014. The purpose of this analysis is to identify differences in the evolution of female homicides between these two groups of municipalities, before and after the introduction of the new penal code. Panel A of Table 3.4 shows the result for the municipality that had experience female homicides but that had not use the *femicide* penalty type. I find that the average female homicides rates decreased over the period 2010-2020, from 4.3 to 2.81 female homicides per 100,000 inhabitants. Similarly, the gender-violence rate decreases across these periods. Panel B of the Table 3.4 shows the evolution of female homicides rates in municipalities that had applied the *femicide* penalty type. In this case, I observe that female homicides rate increased in the 4-year period right after the introduction of the new penal code, and it remained steady in the next periods until 2020. Regarding the gender-violence rates, there is an increase from 1.64 in the period 2010-2013 to 2.51 per 100,000 inhabitants in the period 2014-2017. Moreover, the rate raises up to 2.73 in the last years periods. A possible interpretation of these results is that those municipalities that used the *femicide* penalty type did so precisely due to the large number of previous cases of gender-violence victims. However, it is important to clarify that a large group of municipalities that experienced gender-violence victims during 2010 to 2020 did not used the *femicide* penalty type right after 2014. Indeed, the decision in determining the type of penalty as a *femicide* can be motivated by social media pressure, previous experiences with gender-violence victims, or the judge's decision based on the available proofs and evidence.

I clarify this potential endogeneity problem in the Figure 3.3, which shows the trends on gender-violence victims in the municipalities that eventually enforced or not the *femicide* classification. As shown in the figure, the trends on the victims for these two groups of municipalities are similar before the introduction of the 2014 reform. After the 2014 reform, the municipalities that enforced the *femicide* type of penalty did experienced more gender-violence victims.

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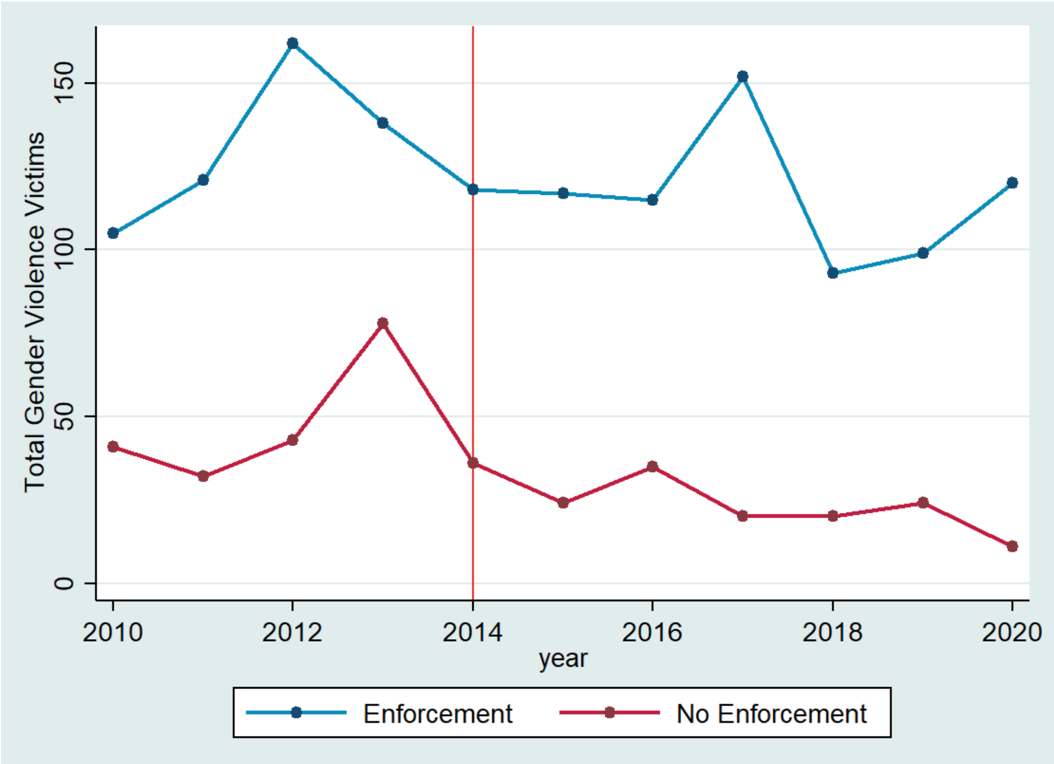
[29] Also, local media has drawn several denounces of impunity here and here. Impunity refers to the failure of judiciary process to determine a specific sentence. An example of impunity is when femicide is not sentenced because the absence of the perpetrator does not allow his judgment. See https://www.planv.com.ec/historias/sociedad/el-feriado-mas-violento-contra-mujeres.

Figure 3.3 – Gender-violence victims by municipalities that enforce or not the *femicide* type of penalty, 2010 -2020



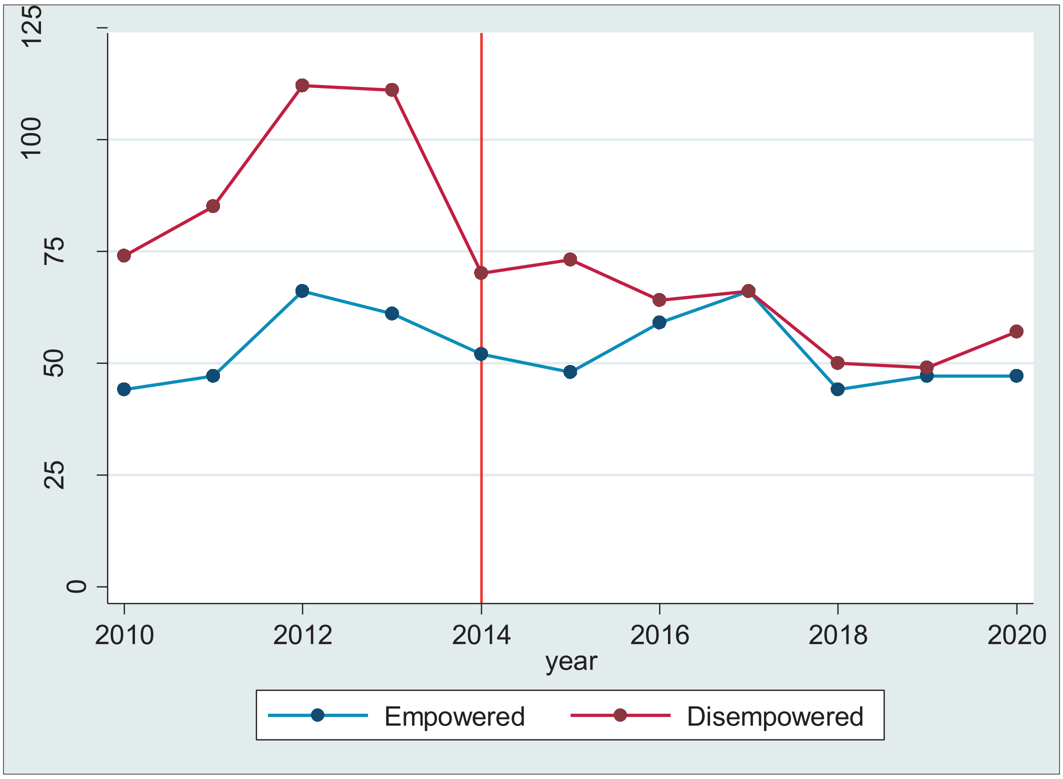
Source: Author's elaboration. Data from the homicides' register.

My analysis of the retaliation effect considers that after the reform of the penal code it could be an increase in women empowerment that caused a male adverse reaction. Women empowerment implies to promote women's self-worth, their ability to determine their own choices, and as such, their capability to refuse and disagree on male partners' dominant behavior. To study this possibility, it is useful to consider the evolution of women empowerment at the municipality level during the period under analysis. For this objective, I use the Victimization and Security Perception survey (hereinafter victimization survey) of the years 2011 and 2019, gathered by the National Institute of Statistics (INEC), in Ecuador. The victimization surveys from 2011 and 2019 are representative at the national level, and each of them includes around 20 thousand respondents across nearly 165 municipalities of all the 24 provinces in Ecuador. Both surveys contain different sections regarding violence in the school, workplace, home, and society in general. Important for this research, these surveys include three sections that analyzes the male/female roles, financial dependance, and life during the relationships. More specifically, these surveys include several questions related to partner dominance and women empowerment behavior. For example, some questions ask to the women if they agree or disagree on her partner's aggressive or controlling behavior, or also if she justifies or not to their male partner's punishment, experience financial (in)dependence; or if they ever have denounced any type of violence. Considering this, I compare whether the share of respondents' answers that agree on male partner's dominant behavior is higher or lower in 2019 relative to the share of women in 2011, at the municipality level. I use this information to estimate the dummy variable $Women\ Empowerment_m$ showing whether women empowerment has increased or not between the periods 2011-2019 in the municipalities of this dataset.

Table 3.5 shows the evolution of female homicide rates in the period 2010 to 2020, by those municipalities that exhibits an increased versus decreased levels of women empowerment in the victimization survey of the year 2019 relative to the survey of 2011. Panel A of the table shows female homicides in municipalities with a decreased level of women empowerment, and Panel B repeats the analysis for municipalities with an increased level of women empowerment levels. Panel A shows that in municipalities with a decreased empowerment level the average female homicides rates decline over the period examined. Similarly, the gender-violence rate decreases in the 4-year period after the law introduction, but it increases in the last period (2018-2020). The other-violence rate also decreases over the 4-year periods from 2010 to 2020. Panel B shows that in municipalities with an increased women empowerment level, the female homicides rate raised in the 4-year period right after the introduction of the new penal code, and it decreases in the last periods until 2020. Similarly, for the case of the gender-violence rates, I observe an increase in the 2014-2017 period, moving from 1.55 to 1.82 gender-violence victims per 100,000 inhabitants. Moreover, the rate decreases to 1.69 in the period 2018-2020. On the other hand, the other-violence rates decrease over the 4-yaer periods. These results suggest that gender-violence cases raised in municipalities that have experienced an increasing level of women empowerment. Indeed, my analysis shows that within the 4-year period after the approval of the new penal code, the rates of female homicides and gender-violence increases in municipalities exhibiting an increased level of women empowerment.

Figure 3.4 illustrates the evolution of the total number of gender-violence victim in municipalities that exhibit an increase and a decrease in the level of women empowerment between 2011 and 2019. We observe that the number of female homicides is lower in the municipalities with an increase in women empowerment. However, the figure also shows a reduction in the differences of gender-based homicides in the two groups of municipalities after the introduction of the new penal code. This convergence in the number of cases for the two groups is in part due to the increase in the number of gender-violence victims in those municipalities with increased women empowerment.

Figure 3.4 – Gender-violence victims by women empowerment at the municipality level, 2010 -2020



Note: The graphic shows the gender-violence victims according to the evolution of women empowerment between 2011 and 2019. Notice that only 100 of the municipalities that recorded female homicides during 2010 to 2020 are included in the victimization survey of 2011 and 2019. Empowered municipalities are those whose share of respondents against male dominant behavior increased in 2019 relative to the share in 2011. The disempowered municipalities are those where the share of respondents against male dominant behavior decreased in 2019 relative to the share in 2011.
Source: Author's elaboration. Data from the homicides' register.

3.4.2 Empirical strategy

This section test for the existence of a retaliation effect after the 2014 reform of the penal code in Ecuador. The analysis of the previous section has shown that the rates of female homicides increased after the introduction of the new penal code in the municipalities that enforced the *femicide* penal type, relative to those that did not. Similarly, I have found that female homicide rates increased in municipalities that present an increase in the level of women empowerment, relative to those in which there is not an increase. Considering this, I estimate a model that examines whether the female homicide rates have increased more in municipalities that enforced the *femicide* penalty type, and that has an increased level of women empowerment. According to the retaliation hypothesis, the increase of women empowerment in the municipalities that have enforced the *femicide* type of penalty should generate a backlash effect on males leading to an increase in violence and the number of female homicides. I test this hypothesis using a sample of the 100 municipalities that registered at least one gender-violence victim between 2010 to 2020, before and after the introduction of the new penal code in 2014, and with available information on women empowerment. Specifically, I estimate the following model:

$$Y_{mt} = \theta_{mt} Women\ Empowerment * Enforcement + \mu_m + \psi_t + \varepsilon_{mt} \qquad (1)$$

where Y_{mt} is the outcome variable (female homicides rates, gender-violence rates, and other-violence rates per 100 thousand inhabitants) in municipality m, in year t. The dummy variable $Women\ Empowerment_m$ takes the value of 1 if the municipality m exhibits an increase in the level of women empowerment in the victimization survey between 2011 and 2019, and zero otherwise. The dummy variable $Enforcement_{mt}$ takes a value equal to 1 from the year at which the municipality m starts to enforce the *femicide* penalty type, and zero before its enforcement. The coefficient of interest θ_{mt} captures the effect of the enforcement of the *femicide* penalty type in the municipalities that exhibits an increased level of women empowerment. The terms μ_m and ψ_t controls for the municipality and year fixed effects, respectively. Finally, I cluster the standard errors at the municipality level. This estimation examines whether the enforcement of the *femicide* penalty type generated a retaliation effect that increased the rates of the women victims.

One possible threat to this estimation is that the enforcement of the *femicide* penalty type in a municipality, captured by the variable $Enforcement_{mt}$, might be correlated with the frequency of previous gender-violence victim cases in that municipality. Despite the sample selection includes only those municipalities that recorded at least one gender-violence victim before or after the enforcement of the *femicide* type, the enforcement could have occurred more in those municipalities that experienced more intensive numbers of gender-violence cases. This issue can imply an endogeneity problem, as the enforcement of the *femicide* classification may not have occurred exogenously across municipalities. For this reason, I estimate a second model to explain the effect of the introduction of the 2014 penal code, rather than its enforcement, on female homicide rates, between municipalities that exhibits an increased versus a decreased level of women empowerment. To do so, I compute the dummy variable Law_t which equals 1 for the periods after the year 2014 and zero before 2014. By doing so, this specification considers that the 2014 reform affected all the municipalities, and it aims to overcome the potential endogeneity on law enforcement. In detail, I test the following estimation:

$$Y_{mt} = \theta_{mt} Women\ Empowerment * Law + \mu_m + \psi_t + \varepsilon_{mt} \qquad (2)$$

where Y_{mt} is the outcome variable (female homicides rates, gender-violence rates, and other-violence rates per 100 thousand inhabitants) in municipality m, in year t. The dummy variable $Women\ Empowerment_m$ takes the value of 1 if the municipality m exhibits an increase in the level of women empowerment in the victimization survey between 2011 and 2019, and zero otherwise. The dummy variable Law_t reflects the 2014 reform, and it takes the value of 1 from the year 2014 onwards, and zero before 2014. The difference with respect to equation (1) is that in the equation (2) the coefficient of interest θ_{mt} captures the effect of the introduction of the new penal code that regulates the femicides (rather than its enforcement) in those municipalities that exhibits increasing levels of women empowerment. The terms μ_m and ψ_t controls for the municipality and year fixed effects, respectively. Finally, I cluster the standard errors at the municipality level.

3.5 Results

Table 3.6 shows the results of the estimation of equation (1), which analyzes whether the enforcement of the *femicide* penalty type generated a retaliation effect that increased the rates of the women victims. The left panel of the table considers the period 2010-20, while the right panel analyze the association for the period 2010-2017, since in the 2018 the Ecuadorian government approved a new legislation to prevent violence against women. Columns (1) and (2) show that female homicide rates and gender violence rates increased in municipalities that exhibit an increased women empowerment level and that enforced the use of the *femicide* penalty type. Specifically, the enforcement of the law lead to a 0.28 SD increase in the female homicide rate, in those municipalities with empowered women. Moreover, the *femicide* enforcement itself lead to a 0.97 SD increase in the female homicide rates. On the other hand, the gender-violence increased by 0.27 SD in the women empowered municipalities that adopted the law using the *femicide* penalty type. Similarly, the law enforcement per se lead to a 1.04 SD increase in the gender-violence rates across all municipalities. In the Column (3) I find that the *femicide* enforcement is not associated with the other-violence rates. In the right panel of Table 3.6, Columns (4) to (6) present the results of the estimation, restricting the analysis to the 2010-2017 period, that is, comparing 4 years before and after the introduction of the penal law. Column (4) suggests that a one SD increase in women empowerment levels leads to 0.46 SD increase in female homicide rates, when the municipality enforces the *femicide* penalty type. The enforcement of *femicide* classification per se leads to a 0.69 SD increase in the female homicide rates. Column (5) suggests that gender-violence rates increase by 0.42 SD for the municipalities with increasing women empowerment levels that have started to enforce the use of *femicide* classification. Similarly, law enforcement leads to a 0.77 SD increase in the gender-violence rates. Finally, Column (6) suggest that there is no association between *femicide* enforcement on other-violence rates, among women empowered municipalities.

Next, I explain the results from the second estimation that analyzes the effects of the 2014 penal code on the women victims' rates. The results of the estimation of equation (2) are expressed in the Table 3.7. As before, the left panel of the Table 3.7 considers the period 2010-20, while the right panel analyze the association for the period 2010-2017, since in the 2018 the Ecuadorian government approved a new legislation to prevent violence against women. Columns (1) and (2) show that after the introduction of the new penal code in 2014, female homicide rates and gender violence rates increased in municipalities with an increased women empowerment level. Specifically, the legislative reform led to a 0.69 SD increase in the female homicide rate, in those municipality with an increased level of women empowerment. On the other hand, the gender-violence rate increased by 0.61 SD in the women empowered municipalities after the penal code reform in 2014. Column (3) shows that the introduction of the new penal code is not associated with the other-violence rates.

Columns (4) to (6) in the right panel of Table 3.7 shows the results of the analysis for the period 2010-2017. Column (4) suggests that right after the legislative reform, a one SD increase in women empowerment levels leads to 0.72 SD increase in female homicide rates. Column (5) suggests that after the 2014 reform gender-violence rates increase by 0.66 SD in the municipalities that exhibits an increased level of women empowerment. Finally, Column (6) suggest that there is no association of the law reform on other-violence rates, among women empowered municipalities.

To sum up, the results of this analysis show that the strategy to avoid future gender-violence victims with the penalization of female homicides might have temporarily created a retaliation effect, in Ecuador. The findings of this paper suggest that enforcing the *femicide* penalty, accompanied with women empowerment, has been associated with a raise in the female homicides and the gender-violence rates, due to the male backlash effect.

These results are in line with the literature that analyzes the adverse effects of social policies in domestic violence. For instance, Hidrobo and Fernald (2013) finds that emotional violence increases by 9 percentage points, in those households where the husband does not have more schooling than his wife, and that receive the cash transfer called *Bono de Desarrollo Humano*, in Ecuador. However, the authors explain that the cash transfer significantly decreases emotional violence by 8 percentage points and controlling behaviors by 14 percentage points, when the male partner education is greater than the female's one. Another example is the reform on mandatory arrest laws that generated a decrease in the victims' reporting to police because of the fear of getting their relatives arrested, leading to an increase in domestic violence (Zelcer, 2014). Additionally, Leisenring (2012) has documented that the legislative reforms of police response to intra-partner violence have not necessarily made an improvement on female victims of intra-partner violence. The author explains that the victims were shown to have a negative perception of responding officers.

These findings appeal for better policies to prevent future female homicides. Some examples of these policies are the laws on discrete and preferred arrests to the perpetrator, the social services in favor of the victims, and the facilitation to report violence. For instance, Chin and Cunningham (2019) finds that discretionary arrest laws (those that allowed officers discretion to make arrests) decreased current and former spousal homicides rates by 0.125. The authors also report that the probability of committing spousal homicides reduces by 35%. Similarly, Xie and Lynch (2017) finds that reporting of crime to the police and the use of victim services, are associated with a 34% and a 40% reduction in the risk of repeat victimization, respectively.

3.6 Conclusion

Female homicides and gender violence victimization is a latent problem in developing economies, where public authorities are adopting several initiatives to prevent new cases. The scientific literature has explained that the potential channels to eradicate this problem are through gender equality and the policies on women financial and social inclusion. However, previous evidence has shown debatable outcomes of these interventions, which are linked to the social context, and the social status of the women.

This paper has analyzed the characteristics of gender-violence victims in Ecuador and the evolution of female homicide rates in the last decade. Using the homicides database, I identify 2167 solved female homicides, and I find that the average age of the female victims was 33 to 34 years old, nearly 60% of the women victims were single, and around 70% of the female homicides occurred in urban areas. Another relevant aspect is that almost 75% of the female homicides were committed with a light-weapon, and 60% of the total took place in a house, hotel, or any other non-public place. I also observe that the evolution of the female homicide is decreasing over time, but that after the introduction of the new penal code in 2014 the proportion of gender-violence victims is increasing, relative to the women victims of other type of violence. In particular, when considering the municipalities that exhibits increasing versus decreasing level of women empowerment, I observe that female homicides rates increased from 1.89 to 2.03, from the periods 2010-13 to 2014-17, in those municipalities with increasing level of women empowerment. I also analyze the evolution of the female homicides rates considering whether the municipalities enforced or not the use of *femicide* type of penalty. I find that in those municipalities that enforced the *femicide* classification, the female homicide rate increased from 2.18 to 2.85 victims per 100 thousand inhabitants, in the period from 2010-13 to 2014-17.

The main contribution of this paper is to examine the existence of a retaliation effect after the approval of the new penal code in 2014. To do so, I first exploit the temporal difference in the enforcement of the *femicide* penalty type, and I find that the enforcement could generate a retaliation effect that led to an increase of female homicide rates and of gender-violence rates, in those municipalities exhibiting an increased level of women empowerment. One aspect to consider is that this analysis assumes that the enforcement of *femicide* is exogenous to the intensity of female homicides and gender-violence rates, which may not necessarily be the case. My second analysis aims to overcome this potential endogeneity problem by examining the effect of the approval of the new penal code in 2014 on the rates of female homicides and gender-violence. The difference with the previous strategy is that this specification controls for the 2014 reform, rather than for its enforcement. This analysis has shown that the introduction of the *femicide* penalty type in the new penal code is associated with the increase in the rates of female homicides and gender-violence, in the municipalities with an increased level of women empowerment. Overall, these results suggest that the intervention on the penalization of crimes against women might have temporarily created a retaliation effect.

The findings of this research go in the same direction as other papers that have studied how gender violence penalization may adversely lead to more women victimization. In particular, my results suggest that the 2014 reform may have temporarily led to more violence. In this matter, previous evidence has argued that such policies to improve women participation and protection measures, are key determinants to reduce gender-violence, but that at the same time these could adversely induce to backlash effects as a rejection response against women empowerment (Zimmerman, 1995; Angelucci, 2008; Dawson, 2016; Whaley and Messner, 2002; Xie et al., 2012; Banerjee, La Ferrara and Orozco, 2019; Bulte and Lensink, 2019; Gibbs et al., 2020). These findings, jointly with my results, imply that interventions should avoid violence against women, and not only to penalize it. Indeed, the studies from Chin and Cunningham (2019), and Xie and Lynch (2017), demonstrates that direct police interventions (including reporting to police and discretionary arrest laws) are key to protect the victim and to prevent future violent events, leading to a reduction in women victimization.

Future research should provide more evidence on the mechanisms to reduce gender violence, and to avoid retaliation effects from legal reforms. Also, administrative information on the alive victims of violence, such as denounces and restraining orders, are crucial for the evaluation of the effects of security services and social support intervention on the victims. Taking this into consideration will lead to a better evaluation and design of public policies to prevent future violence against women.

Tables of Results

Table 3.1 - Time trends of victims' characteristics in Ecuador between 2010 to 2020

Variable	All years	2010 – 2013	2014 – 2017	2018 – 2020
	Percentages relative to total victims			
Gender violence	0.795	0.748	0.837	0.812
	(0.0090)	(0.0153)	(0.0137)	(0.0183)
Private place	0.592	0.464	0.681	0.674
	(0.0110)	(0.0176)	(0.0172)	(0.0220)
Urban area	0.619	0.608	0.620	0.637
	(0.0109)	(0.0172)	(0.0179)	(0.0225)
Age (Mean)	33.85	33.36	33.93	34.57
	(0.4018)	(0.6247)	(0.6721)	(0.8394)
Age groups				
Age 1st Quartile	0.268	0.274	0.275	0.245
(0 – 22)	(0.0099)	(0.0157)	(0.0165)	(0.0201)
Age 2nd Quartile	0.229	0.243	0.223	0.212
(23 – 30)	(0.0094)	(0.0151)	(0.0154)	(0.0191)
Age 3rd Quartile	0.263	0.246	0.255	0.304
(31 – 43)	(0.0099)	(0.0152)	(0.0161)	(0.0215)
Age 4th Quartile	0.241	0.238	0.247	0.239
(44 – 99)	(0.0096)	(0.0150)	(0.0159)	(0.0200)
Penal Type Sentence				
Assassination	0.505	0.517	0.523	0.453
	(0.0112)	(0.0176)	(0.0184)	(0.0233)
Femicide	0.226	-	0.334	0.449
	(0.0094)	-	(0.0174)	(0.0233)
Homicide	0.264	0.483	0.129	0.0941
	(0.0099)	(0.0176)	(0.0124)	(0.0137)
Contract kill	0.00602	-	0.0136	0.00438
	(0.0017)	-	(0.0043)	(0.0031)
Marital status				
Married	0.212	0.229	0.195	0.208
	(0.0091)	(0.0148)	(0.0146)	(0.0190)
Divorced	0.0521	0.0323	0.0545	0.0832
	(0.0050)	(0.0062)	(0.0084)	(0.0129)
Single	0.605	0.512	0.677	0.650
	(0.0109)	(0.0176)	(0.0173)	(0.0223)
Union	0.0972	0.197	0.0368	0.0197
	(0.0066)	(0.0140)	(0.0070)	(0.0065)
Observations	1995	804	734	457

Table 3.2 - Difference in means between gender-violence versus other-violence victims, during 2010-2020

Variable	Other Violence	Gender Violence	Difference
	Mean (SD)		
	(1)	(2)	(3) = (2)-(1)
Age (Mean)	41.58	31.51	-10.069***
	(1.04)	(0.39)	(0.923)
Age groups			
Age 1st Quartile	0.2	0.29	0.082***
(0 – 22 years)	(0.02)	(0.01)	(0.023)
Age 2nd Quartile	0.16	0.25	0.088***
(23 – 30 years)	(0.02)	(0.01)	(0.022)
Age 3rd Quartile	0.22	0.27	0.046**
(31 – 43 years)	(0.02)	(0.01)	(0.023)
Age 4th Quartile	0.41	0.19	-0.216***
(44 – 99 years)	(0.02)	(0.01)	(0.022)
Observations	454	1,703	2,157
Private place	0.5	0.6	0.097***
	(0.02)	(0.01)	(0.026)
Observations	448	1,694	2,142
Urban area	1.64	1.62	-0.022
	(0.02)	(0.01)	(0.026)
Observations	443	1,683	2,126
Work	0.79	0.67	-0.110***
	(0.02)	(0.01)	(0.028)
Observations	326	1,264	1,590
Gunfire used	0.4	0.27	-0.137***
	(0.02)	(0.01)	(0.024)
Observations	455	1,704	2,159
Education level			
None	0.04	0.08	0.035**
	(0.01)	(0.01)	(0.018)
Basic	0.52	0.48	-0.038
	(0.03)	(0.02)	(0.034)
Secondary	0.36	0.38	0.017
	(0.03)	(0.01)	(0.033)
Superior	0.08	0.06	-0.014
	(0.02)	(0.01)	(0.017)
Observations	269	1,063	1,332

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

(Cont.) Table 3.2 - Difference in means between mortal female victims from gender violence versus other type of violence, during 2010 to 2020.

Variable	Other Violence	Gender Violence	Difference
		Mean (SD)	
	(1)	(2)	(3) = (2)-(1)
Penal Type			
Assassination	0.56	0.48	-0.089***
	(0.02)	(0.01)	(0.026)
Homicide	0.42	0.26	-0.159***
	(0.02)	(0.01)	(0.024)
Contract kill	0.01	0.01	-0.001
	(0.00)	(0.00)	(0.004)
Observations	455	1,704	2,159
Marital status			
Married	0.23	0.21	-0.029
	(0.02)	(0.01)	(0.022)
Divorced	0.07	0.05	-0.021*
	(0.01)	(0.01)	(0.012)
Single	0.54	0.62	0.085***
	(0.02)	(0.01)	(0.027)
Union	0.09	0.1	0.014
	(0.01)	(0.01)	(0.016)
Widow	0.07	0.02	-0.049***
	(0.01)	(0.00)	(0.010)
Observations	426	1,602	2,028
Ethnicity			
Afro-Ecuadorian	0.05	0.06	0.012
	(0.01)	(0.01)	(0.013)
White	0.04	0.03	-0.013
	(0.01)	(0.00)	(0.009)
Native	0.03	0.05	0.022*
	(0.01)	(0.01)	(0.012)
Mestizo	0.85	0.83	-0.014
	(0.02)	(0.01)	(0.020)
Montubio	0.02	0.02	-0.004
	(0.01)	(0.00)	(0.008)
Other	0.01	0.01	-0.004
	(0.00)	(0.00)	(0.004)
Observations	416	1,657	2,073

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3.3 - Evolution of female homicides rates across municipalities, during 2010-2020

	2010 – 2013	2014 – 2017	2018 – 2020
	Average rates per 100,000 inhabitants		
Female homicides rate	3.390 (0.4435)	2.826 (0.2839)	2.160 (0.2172)
Gender-violence rate	2.771 (0.4326)	2.340 (0.2706)	1.890 (0.2107)
Other-violence rate	0.619 (0.1031)	0.487 (0.0842)	0.270 (0.0576)
Average population	30,020.0 (3,434.03)	32,050.8 (3,635.09)	33,795.7 (4,393.5)
Observations	1,784	1,784	1,338

Standard errors in parentheses

Table 3.4 - Evolution of female homicides rates in municipalities that have adopted or not the new femicide type, 2010-2020

	2010 – 2013	2014 – 2017	2018 – 2020
Panel A	No enforcement		
	Average rates per 100,000 inhabitants		
Female homicide rates	4.3	2.81	1.63
	(0.73)	(0.44)	(0.30)
Gender-violence rates	3.63	2.21	1.25
	(0.73)	(0.42)	(0.28)
Other-violence rates	0.67	0.6	0.38
	(0.13)	(0.13)	(0.10)
Average population	10,456.88	11,101.18	11,649.72
	(355.85)	(381.55)	(466.85)
Observations	1016	1016	762

Panel B	Enforcement		
	Average rates per 100,000 inhabitants		
Female homicide rates	2.18	2.85	2.86
	(0.34)	(0.31)	(0.31)
Gender-violence rates	1.64	2.51	2.73
	(0.29)	(0.30)	(0.31)
Other-violence rates	0.54	0.34	0.13
	(0.16)	(0.08)	(0.04)
Average population	55,900.43	59,765.45	63,092.89
	(7,869.19)	(8,327.13)	(10,062.73)
Observations	768	768	576

Standard errors in parentheses

Table 3.5 - Evolution of female homicides rates by women empowerment, 2010-2020

	2010 – 2013	2014 – 2017	2018 – 2020
Panel A	No empowerment		
	Average rates per 100,000 inhabitants		
Female homicide rates	2.8	1.35	1.55
	(0.36)	(0.21)	(0.28)
Gender-violence rates	2.15	0.98	1.28
	(0.33)	(0.17)	(0.27)
Other-violence rates	0.64	0.37	0.27
	(0.14)	(0.12)	(0.09)
Average population	74,949.22	79,958.54	84,248.26
	(14,412.74)	(15,241.97)	(18,412.37)
Observations	408	408	306

Panel B	Empowerment		
	Average rates per 100,000 inhabitants		
Female homicide rates	1.89	2.03	1.87
	(0.20)	(0.22)	(0.29)
Gender-violence rates	1.55	1.82	1.69
	(0.19)	(0.21)	(0.29)
Other-violence rates	0.34	0.21	0.18
	(0.08)	(0.06)	(0.07)
Average population	29,214.24	31,203.76	32,907.1
	(2,293.87)	(2,457.72)	(3,001.66)
Observations	576	576	432

Standard errors in parentheses

Table 3.6 - Association between women empowerment and law enforcement on the female homicide rates

	OLS Fixed Effects (Rates per 100,000 inhabitants)					
	All years			2010-2017		
	Female homicides	Gender Violence	Other Violence	Female homicides	Gender Violence	Other Violence
	Coefficients			Coefficients		
	(1)	(2)	(3)	(4)	(5)	(6)
Women Empowerment * Enforcement	0.749*	0.720*	0.0287	1.643***	1.494***	0.149
	(0.4281)	(0.3912)	(0.1430)	(0.5774)	(0.5465)	(0.1804)
Enforcement	2.209***	2.359***	-0.150	2.004***	2.192***	-0.188
	(0.6313)	(0.6007)	(0.1584)	(0.5476)	(0.5060)	(0.2102)
Population size	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Year F.E.	X	X	X	X	X	X
N Clusters	100	100	100	100	100	100
Observations	1100	1100	1100	800	800	800
R2	0.202	0.206	0.159	0.198	0.204	0.176

Note: Each coefficient represents a separate regression of the equation (1). The left-hand side panel regress the output rates for the years 2010 to 2020, using all Ecuadorian municipalities. The right-hand side panel regress the output rates for the years 2010 to 2017. I control for population size of the municipality in all regressions. The standard errors are clustered at the municipality level and are shown in parentheses. Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3.7 - Association between women empowerment and the introduction of the new penal code on the female homicide rates

	OLS Fixed Effects (Rates per 100,000 inhabitants)					
	All years			2010-2017		
	Female homicides	Gender Violence	Other Violence	Female homicides	Gender Violence	Other Violence
	Coefficients			Coefficients		
	(1)	(2)	(3)	(4)	(5)	(6)
Women Empowerment * Law	1.429*** (0.5157)	1.260*** (0.4802)	0.169 (0.1905)	1.584*** (0.5842)	1.447*** (0.5405)	0.137 (0.2190)
Population size	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Year F.E.	X	X	X	X	X	X
N Clusters	246	246	246	246	246	246
Observations	2706	2706	2706	1968	1968	1968
R2	0.0978	0.105	0.0953	0.133	0.143	0.129

Note: Each coefficient represents a separate regression of the equation (2). The left-hand side panel regress the output rates for the years 2010 to 2020, using all Ecuadorian municipalities. The right-hand side panel regress the output rates for the years 2010 to 2017. I control for population size of the municipality in all regressions. The standard errors are clustered at the municipality level and are shown in parentheses. Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4 Chapter 4 – The aftermath of crime: Indirect exposure to homicides, maternal stress, and newborns' health

4.1 Introduction

Maternal and child health are included within the Sustainable Development Goals (United Nations, 2015). While nutrition and socio-economic conditions are key factors for maintaining good pregnancy conditions, direct and environmental exposure to violence are essential aspects for pregnant women's well-being. Violence and insecurity affect the living conditions of societies, especially among the most vulnerable sectors of the population, such as the pregnant women, the children, and newborns (Duque, 2017; Sharkey et al., 2012). Beyond the negative effects on socio-economic outcomes, violence is likely to induce fear and psychological stress for individuals who are directly or indirectly exposed to it, especially pregnant women (Aizer, 2016; Koppensteiner and Manacorda, 2016; Currie et al., 2020). Direct exposure to violence has been associated with severe damage to fetus health conditions including birth weight, preterm incidence, cognitive capacity, and negative neurodevelopmental consequences (Dunkel-Schetter, 2011; Radtke et al., 2011; WHO, 2013; IACHR, 2019; Walsh et al., 2019). However, little is known about how maternal stress and fear generated by violent crimes can damage fetal health. The objective of this paper is to explore whether the indirect exposure of mothers to violence during pregnancy can affect newborn health. More specifically, I study the impact of indirect exposure to homicides on newborn health outcomes in Ecuador.

There is an increasing number of studies examining the consequences of violence and maternal stress on children's health. This literature has found empirical evidence that birth weight, gestation length, and in-utero survival are affected by land mine explosions (Camacho, 2008) and civil conflicts and war (Mansour and Rees, 2012). Other papers have shown the persistent effects of street and domestic violence on newborn and infant health (Aizer, 2016; Currie et al., 2020; Hoffman et al., 2016). Nevertheless, very few studies have analyzed the effects of indirect exposure to homicides on birth outcomes (Koppensteiner and Manacorda, 2016; Goin et al., 2020). Violent crime generates fear, anxiety, and stress for mothers during the gestational period and this can cause severe negative neurodevelopmental consequences to the newborn (Dunkel-Schetter, 2011; Sharkey et al., 2012), as well as cognitive deterioration (Duque, 2017). Moreover, high levels of stress may lead to a reduction in the length of gestation and an increased probability of low birth weight (Pun et al., 2019; Walsh et al., 2019). Considering this, policies to reduce the effects of violence should be designed considering the indirect impact of crime on the neighborhood population, and especially on newborns and pregnant mothers.

Violence is a significant problem in Ecuador, although, the number of homicides has dropped considerably in recent years. While the homicide rate reached 17.9 per 100,000 inhabitants in 2008, the rate had fallen to 5.8 per 100,000 inhabitants by 2018, implying that Ecuador is one of the Latin American countries with the lowest homicide rates (Brotherton and Gudé, 2018). This trend has slightly reversed during the years 2019 to 2021, with an increase in the homicide rate to 6.1 by 2020. Most of this criminal activity takes place in the cities of Guayaquil and Quito. In the last few years, the country has significantly increased the resources and technologies dedicated to reducing crime (MCS, 2011; MIES, 2012). Since 2011, the central government, with the support of the Inter-American Development Bank, has reformed the police force to enhance the hiring and training process, increasing police salaries and the number of reporting desks in each local community for reporting violence, as well as adopting modern crime prevention technologies. Moreover, in 2014, the government passed a new penal code that has increased the penalties for existing crimes, such as kidnapping, and includes new types of homicides, such as femicides and contract killing. In spite of these important changes, there are very few policies designed to mitigate the effects of violence and offer legal and medical support to the direct and indirect victims in Ecuador. One exception is the norms and protocols released by the Ministry of Health in the year 2008 to assist women and children that were victims of sexual, domestic and gender-based violence, and to those who witnessed violent crimes (Ministerio de Salud, 2008).

The objective of this study is to examine the effects of indirect exposure to crime on newborn health outcomes (for instance weight at birth, Apgar score at the first minute and gestation length) in Ecuador. Analyzing the causal effects of salient criminal events on nearby residents entails two significant difficulties. Firstly, household addresses are usually not available for confidentiality reasons and, as a result, location is usually approximated using the centroid of the reported neighborhood or municipality (Camacho, 2008; Mansour and Rees, 2012; Koppensteiner and Manacorda, 2016; Aizer, 2011; Torche 2011). Moreover, the lack of precise information on the occurrence of the crime events generates inaccuracies on exposure measurement and bias in the estimates (Koppensteiner and Manacorda, 2016). This paper overcomes these problems with the creation of an exposure variable based on the geolocation of the mothers during pregnancy and the location of the occurrence of each homicide. For each mother, I create buffers of a 1- and 5-kilometer radius from their home address, which consider the aggregated number of any type of homicides that occurred within the buffer area. I use this information to construct two exposure variables.

Firstly, I consider an exposure variable that reflects whether or not the mother was exposed to one or more homicides during pregnancy. This variable offers a measure of maternal stress caused by homicides that I use to analyze the effect on environmental violence on newborn health. Secondly, I calculate an exposure variable showing the intensity to which each mother was exposed to crime in the five years before the birth. I use this variable to test whether historical environmental exposure to crime attenuates maternal stress caused by the indirect exposure to crime during the pregnancy period.

Secondly, there is a concern that households living in or close to areas with endemic criminal activity might have different characteristics than those living at a distance from them, and for this reason, it is difficult to disentangle the causal impact of crime from unobservable factors that systematically affect newborn health (Aizer, 2011; Koppensteiner and Manacorda, 2016; Currie, Mueller-Smith, Rossin-Slater, 2020). To solve the endogeneity of the indirect exposure to a crime, I use three identification strategies that closely follow the analysis of Koppensteiner and Manacorda (2016) for Brazil, and the study of Currie, Muller-Smith, and Rossin-Slater (2020) for NYC. Firstly, I analyze the impact of crimes considering the variation in the intensity of crimes within municipalities. To do so, I use an empirical approach with municipality fixed effects that estimates the difference in birth weight between infants born to mothers who were exposed to high versus low levels of homicides in their municipalities.

The second identification strategy estimates a difference-in-differences specification that compares the difference between being exposed or not exposed to a homicide during pregnancy, relative to being exposed or not exposed to a homicide within the 9 months following the birth of the newborn. This approach follows the identification strategy of Black et al. (2016), Persson and Rossin-Slater (2018) and Currie, Mueller-Smith, and Rossin-Slater (2020), and it enhances the comparability among treated and controlled group of mothers, assuming that the determinants of crime occurring around the mothers are similar for the treated and comparison groups.

The third identification strategy considers a sub-sample of mothers that had more than one child during the period 2015 to 2017 and controls for the maternal fixed effects. During the period under examination, a relevant percentage of mothers experienced different levels of exposure to homicides over the course of their pregnancies. This situation allows me to analyze the effect on birth weight on different levels of exposure to crimes on siblings from the same mother.

This paper draws on two public data sets. Information on newborn health outcomes is obtained from the National Register of Live Births (*Registro estadístico de nacidos vivos*) for the period 2010 to 2018. This data set contains information for nearly 495,000 newborns and includes several observable characteristics of children and mothers.[30] Moreover, it was possible to obtain additional information from the Ecuadorian National Statistics Office (INEC) on the mothers' home addresses during pregnancy for the period 2015 to 2017. In this period, nearly 265,000 newborns were born to mothers living within 1 kilometer of recorded homicides[31]. The newborn data set is complemented with information on crimes from Ecuador's registry of homicides, for the period 2010 to 2018, gathered from the INEC on behalf of the Ministry of the Interior. This registry includes information on different types of homicide[32], the date and the point coordinates of the occurrence of homicides. I combine the two data sets to build the variable measuring newborns' exposure to homicides.

The results from this investigation confirm the hypothesis that maternal stress caused by indirect exposure to homicides has a relevant impact on newborn health outcomes. The first identification design shows that newborns who were exposed to more homicides rates in their municipality, have a birth weight loss of around 30 to 60 grams. Interestingly, this effect is larger in municipalities with very few homicides, suggesting that mothers who are frequently exposed to more homicides are less affected by the stress associated with an additional crime. The second estimation compares the indirect exposure of mothers to homicides within 1 kilometer, during their pregnancy, to mothers with an analogous indirect exposure in the 9 months after the pregnancy. In this case, I find that exposed newborn girls have a birth weight deficit of 20 grams, in municipalities with few homicides. When I expand the radius distance to 5 kilometers, the effects decrease to 11 grams. Moreover, I test whether maternal stress related to indirect exposure to homicides is attenuated when they were exposed to other crimes in the years before pregnancy. Once I consider this control, I find a smaller birth weight deficit of between 5 to 12 grams for newborn girls, confirming the idea that living in a neighborhood frequently exposed to violence attenuates maternal stress generated by homicides during pregnancy. Finally, the third identification strategy uses a maternal fixed-effects estimation to compare siblings exposed and not exposed to crime. The results show that male newborns have a birth weight deficit of almost 111 grams, relative to their male siblings who were less exposed to crime. Overall, the results obtained highlight the importance of establishing social and health policies designed to offer prenatal controls and psychotherapy to safeguard the mental health of mothers exposed to violence during pregnancy.

[30] Similar to most health data sets, this register does not include information on epinephrine or cortisol levels, which are the most common biometric measure of stress. In the absence of a direct measure of stress, a frequent approach in the literature is to consider exogenous events that can cause maternal stress and affect children's health.
[31] I test for the robustness of the results with an analysis considering a 5-kilometer radius. In this case, 363,000 newborns were close to a recorded homicide.
[32] The Ministry of Interior records each event considering the four penal types of homicides stated in the *Código Orgánico Integral Penal* (COIP, 2014): assassination, femicide, homicide, contract killing.

Moreover, policy interventions should include all women and newborns living in the neighborhoods more exposed to crime, in addition to the direct victims of violence.

Related literature. This research contributes to the literature that analyzes how environmental and socio-economic shocks affect in-utero health. The literature has shown the relevance of economic crises and income shocks (Bozzoli and Quintana-Domeque, 2014; Burlando, 2014)[33], natural disasters such as floods, hurricanes, or earthquakes (Rosales-Rueda, 2018; Currie, Rossin-Slater, 2013; Torche, 2011), and rainfall shocks (Pereda et al., 2014; Rabassa et al., 2014). Other papers have demonstrated that newborn health is negatively affected by air pollution through toxic plants and industrial activity (Currie et al., 2015; Chen, Ebenstein, Greenstone, Li, 2013), wildfires in agriculture, (Rangel and Vogl, 2019), or pesticides from aerial fumigation (Calzada, Gisbert, Moscoso, 2021). Some papers have also reported that in-utero health and survival are affected by environmental regulations (Greenstone and Hanna, 2014; Tanaka, 2015) and indoor pollution (Hanna, Duflo and Greenstone, 2016; Barron and Torero, 2017).

A segment of the literature more connected with the present work analyses the impact of maternal stress on birth outcomes. External factors such as war, conflicts, crisis, and stressful conditions are not controlled by pregnant women and can affect fetal health.[34] Several papers have documented the effects on newborn health derived from maternal stress caused by a loss of a family member during pregnancy (Persson, Rossin-Slater, 2018), terrorist attacks (Quintana-Domeque, Ródenas-Serrano, 2017), mafia activities (Torche, Villarreal, 2014), and exposure to weather shocks such as hurricanes (Currie, Rossin-Slater, 2013). These and similar studies have shown that conflict events and terrorism cause maternal stress and exacerbate gestation length and birth weight, especially when it occurs in the first trimester of pregnancy (Camacho, 2008; Torche, 2011; Vinkelsteijn et al., 2004; Ahern et al., 2018; Hoffman et al., 2016). Currie and Rossin-Slater (2013) conclude that stress increases the probability of an abnormal condition of the newborn, as well as the incidence of low birth weight and gestation length. Persson and Rossin-Slater (2018) examine the impact of in-utero exposure to family ruptures and bereavement on newborn health outcomes. They

[33] Van den Berg, Paul, and Reinhold (2020) show that economic downturns may be beneficial in reducing very low birth weight incidence and mortality within the first 28 days after birth, in the context of Sweden. The authors argue that a possible non-tested mechanism of this effect is the reduction of air pollution during economic recession.

[34] Maternal stress due to external shocks causes and increases the epinephrine levels causing a constriction of blood vessels that can limit the flow of blood to the fetus causing growth retardation (Mulder et al., 2002; Vinkelsteijn et al., 2004). The medical literature also suggests that stress during pregnancy increases levels of Corticotrophin-Releasing Hormone (CRH) and generates intra-uterine growth restriction. The CRH regulates the duration of pregnancy and fetal maturation and thus increases the risk of adverse birth outcomes (Wadhwa et al., 1993).

show that the death of a relative up to three generations apart during pregnancy increases take-up of medications during childhood, and anti-anxiety and depression medications in adulthood. Moreover, it negatively affects physical health at birth and increases the likelihood of hospitalization in the first year of life. Quintana-Domeque and Ródenas-Serrano (2017) conclude that in-utero exposure to terrorism during the first trimester of pregnancy leads to lower birth weight and increases the prevalence of low birth weight and abnormal conditions. Moreover, they find that exposure to bomb casualties increases fetal deaths. Similarly, Tapsoba (2020) finds that the risk of conflict increases the likelihood of mortality. In his paper, he compares mortality between children from war and non-war areas and finds that exposure to high risk of violence increases infant mortality by more than 50% in both Ivory Coast and Uganda. In contrast to these studies, Torche and Villarreal (2014) find that in-utero exposure to homicides in the first trimester of gestation increases infant birth weight and reduces the proportion of low birth weight. Their finding is explained by mothers increasing health-enhancing behaviors, such as the use of prenatal care.

This paper closely follows the studies analyzing the effects of assaults and street violence on newborn health (Koppensteiner and Manacorda, 2016; Currie, Muller-Smith, and Rossin-Slater, 2020). The former authors analyze the birth outcomes of newborns whose mothers were exposed to violence in their local environment during pregnancy in Brazil. The authors compare birth outcomes of mothers living in the same neighborhood but that had different exposure to homicides during pregnancy. Currie, Muller-Smith, and Rossin-Slater (2020) study the effects of in-utero exposure to assaults and violent crime on health at birth by matching records from the mothers' addresses in the birth records data to the crimes' exact location in criminal records data, in New York City. They address endogeneity by comparing birth outcomes between women who report an assault during and after pregnancy. Moreover, they test for differences in birth outcomes of women exposed to an assault and to a different type of violence against women, during and after pregnancy. Finally, they use a maternal fixed-effects strategy to compare two pregnancies of the same mother, where one was affected by an assault and the other was not. They find that being exposed to an assault during pregnancy has several adverse consequences for infant health (low birth weight, preterm, low Apgar score, congenital anomalies, admission to intensive care units and mortality). The empirical approach in this paper closely follows the estimation strategies of these two papers to examine the effect of maternal stress generated by crime on newborn health. The contribution in regard with the study by Koppensteiner and Manacorda (2016) is that I am able to compute an exposure measure at the newborn level, which allows me to identify whether or not the newborn was exposed to a homicide in the mothers' surrounding area. Moreover, another contribution with respect to Currie, Muller-Smith, and Rossin-Slater (2020) is that I consider the effect of indirect exposure to homicides in the neighborhood rather than the effects of direct assaults and, to do so, I combine precise data on the mother's home addresses during pregnancy and the homicides that took place in the country of Ecuador as a whole. Furthermore, the analysis includes controls for past exposure to violent crimes and shows that it can attenuate maternal stress. Finally, one of the main contributions is that I am able to control for the mother intrinsic characteristics, estimating a maternal fixed-effects model.

The rest of the paper is organized as follows. Section 2 describes the homicides criminal activity in Ecuador, the penal categories of homicides and their potential health impact. Section 3 describes the data and the merging strategy. Section 4 explains the empirical strategies used to overcome the potential endogeneity of exposure to homicides. Section 5 presents the results. Finally, Section 6 summarizes the main results and discusses the public policy implications.

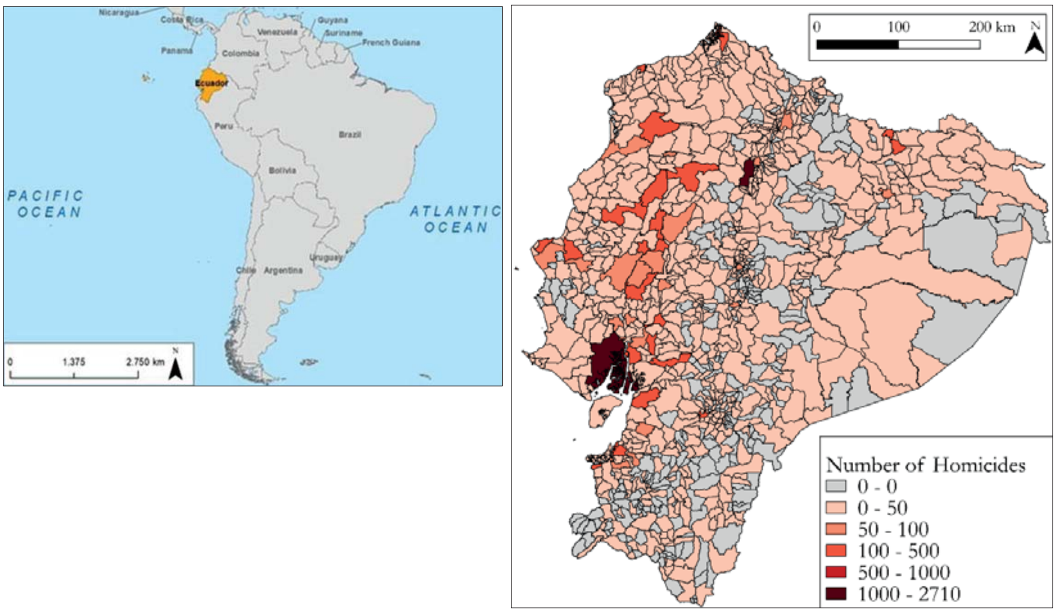
4.2 Background of Crime in Ecuador

Intentional homicides in Ecuador have been declining over the last few decades. After a peak of almost 18 homicides per 100,000 people in 2008, the homicide rate decreased to 5.7 per 100,000 people in 2018 (UN Office on Drugs and Crime's International Homicide Statistics database, reported in the World Bank statistics). Criminal activity has worsened from 2019 to 2021 following the unrest in response to the fiscal policy on subsidies in October 2019, and the economic-pandemic crisis from April 2020 onwards. These events led to a reduction in the public policy budget for security, accompanied by an increase in organized crime and the jail crisis. In addition, local corruption levels increased due to overpricing and controls on the supply of medicines and hospitals, imposed during the pandemic crisis. As a result, the higher levels of violent crimes refer to those related to contract killings and assassinations, and female homicides. According to the latest statistics, during the economic-pandemic crisis, the homicide rate increased by 6.1 per 100,000 inhabitants in the year 2020 (INEC, 2020).

Between 2010 and 2018, there were nearly 14,000 homicides, and the most common cases were: (1) community violence (48%), which refers to homicides that result from emotional violence, and fights and disputes between the members of the community; (2) quotidian crime (38%), which is the result of criminal activities, such as robberies; and (3) domestic violence (13%), which usually refers to femicides (Ministerio de Gobierno, 2019; INEC, 2020; Pontón et al., 2020).

Homicides are mostly concentrated Ecuador's two main cities: Guayaquil and Quito. In fact, these two cities accounted for nearly the 28% of all homicides that occurred during the period 2010 to 2018 (INEC, 2020). From 2007 to 2013, several policies were designed to target these two cities and the government created specialized bodies (*Dirección Nacional de Delitos contra la Vida,* DINASED) to control criminal activity, and to help communities to report criminal activities. Moreover, the government launched a program "*Los más buscados*" ("The most wanted") to encourage civilians to give information on criminals (Ministerio del Interior, 2014). However, homicides are a relevant problem in most Ecuadorian municipalities. In the period 2010 to 2018, around 78% of the nearly 1,500 municipalities recorded at least one homicide (INEC, 2020). Moreover, the average homicide rate at a municipality level is nearly 12 homicides per 100,000 inhabitants, and this number increases as the population size falls in small municipalities, with the absolute number of homicides shown to be similar to other medium or large municipalities. Figure 4.1 shows the total number of homicides in Ecuadorian municipalities between 2010 and 2018.

Figure 4.1 – Homicides distribution in Ecuador (2010-2018).



Note: The graphic on the left shows the location of Ecuador in the South American Continent. The graphic on the right shows the total number of homicides by municipality in Ecuador, from 2010 to 2018.
Source: Author's elaboration based on data from the homicides register.

The declining trend of crime in Ecuador is associated to public policy interventions that took place from 2007 to 2014 that aimed to reduce the conflicts between organized groups of criminals. To achieve this, in 2007, the Ecuadorian government introduced a cultural integration process to allow organized crime groups to become legally recognized organizations and to resolve their conflicts through mediation and arbitration.[35] This policy intended to boost the social inclusion of these groups and generate a cultural transformation that enabled the elimination of violent behavior (Brotherton y Gudé, 2018). Other factors that may explain the drop in the number of crimes in this period include the increase in the size of the police force, the creation of new offices and desks to receive crime reports (MCS, 2011; MIES, 2012), the launch of the 911 telephone line in 2012 (MCS, 2011), and strengthening programs to capture and dismantle illegal criminal groups (Pontón et al. 2020).

Furthermore, in 2014, the Ecuadorian government approved the new penal code (*Código Orgánico Integral Penal*, hereinafter COIP)[36], which included new types of crimes and established stronger penalties for homicides. The COIP reclassified homicides in four types and established new penalties for each: assassination, femicide, homicide and contract killing. By doing so, this regulation aimed to reduce violent crimes and provide a legal framework for punishing crimes. Figure 4.2 shows the evolution of the four types of homicide defined in the COIP, for the years 2010 to 2018.[37] The figure shows a drop in the absolute number of homicides from 2010 to 2014, with the number of homicides remaining stable from 2014 onwards. Nevertheless, since 2014, nearly 1,000 homicides have been recorded each year, equivalent to a rate of around 5.9 homicides per 100,000 inhabitants.

In short, the number of homicides in Ecuador has been very stable since 2014. Therefore, the results of the analysis for the period 2015 to 2017 should not be affected by large changes in the number of homicides that could affect a certain cohort of newborns differently. Moreover, I will assume that maternal stress generated by the environmental exposure to crime should not have been affected by the policies introduced in the previous periods.

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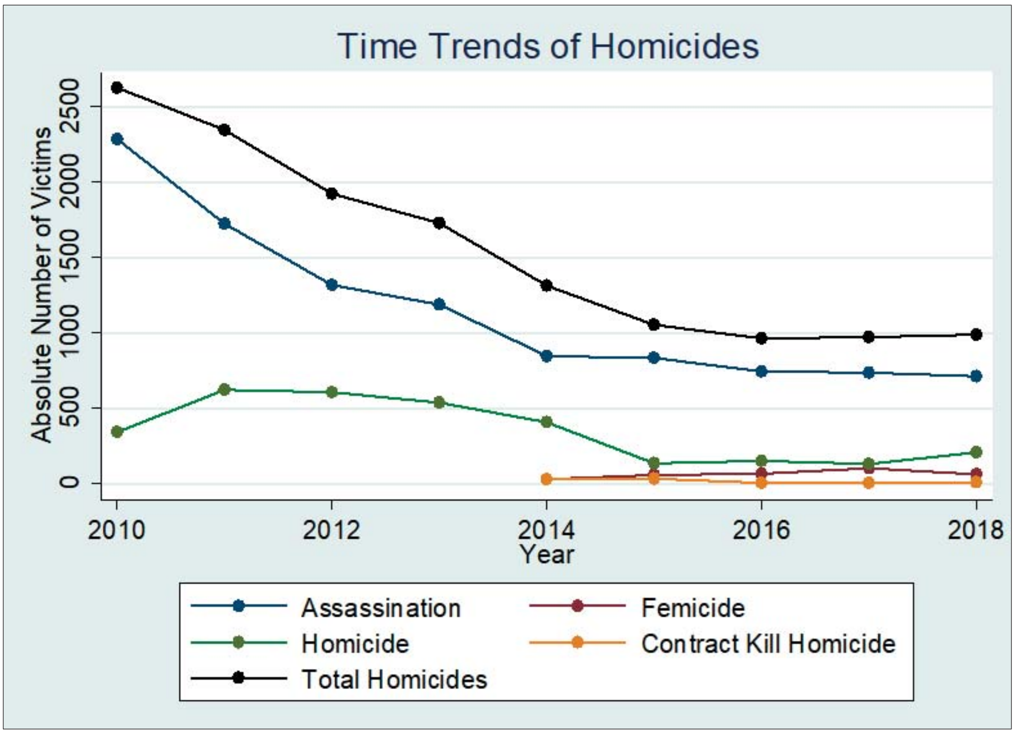
[35] *Registro Oficial No. 228*, published on 10th December 2007, Quito.

[36] The *Código Orgánico Integral Penal* (COIP) was approved in 2014.

[37] Note that the new legislation includes femicide and contract killing as a new type of crime since 2014.

Figure 4.2 – Evolution of each type of homicide in Ecuador (2010-2018).



Note: Femicides and contract kill homicides were introduced as a homicide type in the 2014 reform of the penal code, before which, these cases were recorded as assassination or homicides. The black line represents the total number of victims.
Source: Author's elaboration. Data from the homicides' register.

4.3 Data and merging strategy

This paper combines two different administrative data sets from Ecuador: (1) The National Register of Live Births (*Registro estadístico de nacidos vivos*) for the period 2010 to 2018; and (2) the National Registry of Violent Deaths (*Registro nacional de muertes violentas)* from 2010 to 2018.

Newborn register

The National Register of Live Births of the National Institute for Statistics and Census (INEC) is a data set containing information for all newborns in Ecuador. The data set includes information for nearly 350,000 newborns per year across the whole country for the period 2010 to 2018. Information on newborns including the mother's address during pregnancy is only available for the period 2015 to 2017 and, after a filtering process to eliminate imprecise locations and inaccurate addresses, it contains data for around 495,000 newborns.

The information of newborns includes the birth weight measured in grams, the gestation length in weeks, and the Apgar score at the first minute[38], which are the outcome variables used in the empirical analysis. In addition, it contains information about birth conditions (number of prenatal controls, type of delivery, number of previous births, multiple births, C-section dummy) and newborn characteristics (sex, birth order). The data set also includes characteristics of the mother (education level, ethnicity, marital status) that, according to the economic literature, are relevant factors for newborn health outcomes (Bharadwaj, Loken, and Neilson, 2013; Almond and Currie, 2011; Almond, Chay and Lee, 2005). In the same way as Bozzoli and Quintana-Domeque (2014), I focus on mothers aged 15 to 49 and I exclude newborns whose weight was either under 500 grams or above 9,000 grams. In line with Larsen et al. (2017), I also exclude very premature births with a gestation of less than 26 weeks and births at later than 50 weeks.

Table 4.1 presents the mothers' characteristics considering different samples. Column (1) shows the mean statistics for the whole set of newborns from 2010 to 2018. Columns (2) to (5) show the mean statistics of newborns from 2015 to 2017 for which I have precise information on the mothers' home address. Column (2) shows the mean statistics for the whole set of newborns from 2015 to 2017. Column (3) presents information on newborns from mothers not exposed to a homicide during pregnancy but exposed in the 9 months after the pregnancy period. Column (4) shows the summary statistics of newborns from mothers exposed to a homicide during pregnancy (within a radius of 1 kilometer from the mothers' residence) but who were not exposed to a homicide in the 9 months after the pregnancy. Column (5) includes the newborns born to mothers exposed to a homicide during pregnancy and also in the 9 months after the birth. Column (6) shows the difference in means test between columns (4) and (3). I find that differences between the mothers in terms of ethnicity, marital status, and pregnancy conditions are not statistically significant. The mothers' age and level of education are found to show a different distribution between the two groups, although the difference in their mean is close to zero. Potential differences in the characteristics of the two groups are tackled after controlling for birth cohort fixed effects, municipality fixed effects and maternal fixed effects.

Homicides register

Information on homicide events comes from the national homicides register of Ecuador gathered by the *Ministerio del Interior* (Ministry of the Interior). I use the

[38] The Apgar score assesses fetal health at birth on a 0-10 scale observing the newborns' appearance (skin color), pulse (heart rate), grimace function (reflexes), activity (muscle tone), and respiration (breathing rate and effort). Scores below 7 are considered low. See: https://kidshealth.org/en/parents/apgar.html

information from the years 2010 to 2018, which is the period for which the geographical coordinates of the occurrence of homicides are available. The data includes information for nearly 3,000 homicides per year across the whole country.

The data set includes the types of homicides (assassinations, femicides, homicides and contract killings) in line with the definitions of the penal code (COIP). Additionally, it contains information about the characteristics of the victims (sex, ethnicity, education) and each homicide's attributes (the place and date of occurrence, type of weapon, and whether it occurred in a public or private place). According to the economic literature, the characteristics of the homicide are relevant for examining their effects on maternal stress and newborn health outcomes (Goin et al., 2019; Koppensteiner and Manacorda, 2016; Currie, Mueller-Smith, and Rossin-Slater, 2020; Aizer, 2011).

I use the homicide register data to create two variables that measure exposure to violence at the municipality and neighborhood levels. Firstly, for the period 2010 to 2018, I create an exposure variable that measures the homicide rates at a municipality level. Specifically, I define the $HomicideRate_{mt}$ variable that computes the total number of homicides per 100,000 inhabitants, per municipality per year. This is the exposure variable that I will use in the first identification strategy, in line with the methodological approach of Koppensteiner and Manacorda (2016).

Secondly, for the period 2015 to 2017, I combine the information on the mothers' location and the homicide point coordinates to construct an exposure variable that reflects the newborns' indirect exposure to homicides. Specifically, I use a geographical information system (GIS) to compute the number of homicides that occurred within a radius of 1 km (or 5 km) from the mothers' residence during pregnancy. This approach assumes a linear psychological impact of indirect exposure and distance, similar to the medical and psychological literature that analyzes the effects of neighborhood violence on stress levels for small-scale population in Brazil (Santos et al., 2021), Colombia (Cuartas and Roy, 2019), and in the United States (Fowler et al., 2009).[39] Indeed, Santos et al. (2021) use a similar 1-km radius buffer to analyze neighborhood violence during pregnancy and birth outcomes in São Paulo's Western Region (Brazil), using a sample of 5,268 newborns. In their paper, the authors employ multivariate logistic regressions to examine the associations between violence exposure and birth outcomes.

The exposure variable assumes that homicides occurring closer to the mother's home address generated a stressful situation for the mother that negatively affected her newborn's health. More precisely, the continuous variable $NHOM_{iT}$ measures the number of homicides that indirectly affected the mother of newborn i in the T^{th}

[39] Further psychological literature suggests that psychological stress has four distance dimensions from a stressful event such as where it occurs (proximity), when it occurs, to whom it occurs and whether it occurs (Trope and Liberman 2010; Jackson and Gouseti, 2015).

gestation trimester, using the exact date of the homicide, the birth, and the gestation length. The literature shows that subsequent numbers of stressful events during the pregnancy may be alleviated with advancing gestation periods. Specifically, Entringer et al. (2010) show that, among pregnant women, there is a progressive attenuation of psychophysiological stress responses to additional numbers of violent events as gestation progresses. Therefore, the assessment of the exposure to homicide with the continuous variable $NHOM_{iT}$ may be biased with attenuation responses to more stressful events during advance pregnancy. In view of this, I also create the binary variable $T^{th} Homicide\ Exposure_i$ to reflect whether the newborn i was affected by any homicide during any of the T^{th} gestation trimesters:

$$T^{th} Homicide\ Exposure_i = \begin{cases} 1 = \sum_{T=1}^{T=3} NHOM_{iT} \geq 1 \\ 0 = \sum_{T=1}^{T=3} NHOM_{iT} < 1 \end{cases} \quad (1)$$

where $\sum_{T=1}^{T=3} NHOM_i$ is the total number of homicides that occurred within a 1-km radius of the mother during each of the T^{th} gestation trimesters.[40]

Then, I also create a binary variable that reflects whether a newborn was exposed to a homicide during the 9 months after birth. The purpose of considering this variable is to create a sample that includes mothers indirectly exposed to homicides during and after the pregnancy. Following the empirical approach of Currie et al. (2020), I will use this sample in the analysis of the second and third identification strategies.[41]

I identified nearly 265,000 newborns whose mothers resided within a 1-km radius of a recorded homicide during pregnancy or within the 9 months after birth, in the period 2015 to 2017. From this sample, the group of women who were exposed to homicides during their pregnancy had, on average, 2.2 incidents within 1 km of their home address. Moreover, the group of women whose exposure occurred in the 9 months after birth had almost 2 incidents within 1 km of their location. Figure 4.3 illustrates the data available, showing the location of mothers' home address (red dots) and the location of the homicides (black dots). The figure shows that the mothers from a particular neighborhood can be exposed to several homicides at different distances.

[40] The use of a binary measure of exposure is justified because the functional form of the relationship between homicide exposure and birth outcomes is not well understood and it may be nonlinear.

[41] I also include the sample of children whose mother were indirectly exposed to a homicide during and after pregnancy to increase the statistical power to identify the coefficients of the other variables in the regression estimation.

Figure 4.3 – Mother and homicide locations: illustration

Note: The mothers' home address is represented in red dots, and homicides in black dots. As an illustration, this figure shows the distribution of the mothers' residences and homicides in a neighborhood of Guayaquil in the period 2015 to 2017. Note that the geographical information on newborns and homicides are available for each year in the same period, so the mothers illustrated in the figure may or may not have been exposed to a homicide during their pregnancy.
Source: Author's elaboration. Data from the newborns and homicides registers.

I also compute the variable $Past\ Exposure_i$, which reflects the homicide density at the mothers' home address in the five years before pregnancy. Specifically, for each homicide, I compute a 5-km radius buffer that reflects its potential impact in the surrounding population. Then, for each year, I use a kernel density estimation (KDE) that uses the standard shape (quartic) to calculate the density of homicides in Ecuador. (Appendix B explains the geographic information system tools used to compute this density). Taking this into account, the variable $Past\ Exposure_i$ aggregates the homicide densities at the mothers' home address for the five years before pregnancy:

$$Past\ Exposure_i = \sum_{Y=-5}^{Y=0} Density_{iY} \qquad (2)$$

where $Density_{iY}$ is the homicide densities at the mothers' home address in the year Y before pregnancy. The variable $Past\ Exposure_i$ reflects the intensity of homicides in the mothers' neighborhood and therefore reflects how used the mother is to homicides. I use this variable to test for the hypothesis that living in an area that has previously been affected by homicides might attenuate maternal stress linked to the exposure to a homicide during their pregnancy.

4.4 Empirical strategy

This section presents the three identification strategies developed in this research. Firstly, I develop a fixed-effects estimation that compares the birth weight of newborns that were indirectly exposed to different homicide rates in their municipalities during the pregnancy period, using the sample from the period 2010 to 2018. Secondly, I use a DID specification to examine the effects of being exposed or not exposed during pregnancy, relative to the analogous difference of being exposed within the 9 months following the birth of the newborn. To do so, I use an exposure variable that accounts for the number of homicides that took place within a 1-km (or 5-km) buffer radius from the mothers' residence. This analysis is restricted to the period 2015 to 2017, which is when the information on the mother's residence is available. Finally, I estimate a maternal fixed-effects specification that considers a sample with the mothers who had several children in the period 2015 to 2017, taking into account the fact that each pregnancy was subject to different level of exposure to homicides.

Exposure to violence in the municipality

The first identification strategy estimates the difference in birth weight of infants born to mothers living in the same municipality but who were exposed to different homicide rates. This approach provides a method to control for unobserved time-invariant municipality characteristics and for aggregate time effects. The empirical estimation is the following:

$$Y_{imt} = \beta_0 + \beta_1 HomicideRate_{mt} + \beta_2 X'_{it} + d_m + d_t + u_{imt} \qquad (3)$$

where Y_{imt} is the individual outcome variable (birth weight, gestational length, and Apgar score at 1st minute) of newborn i, in municipality m at time t. $HomicideRate_{mt}$ is the municipality's homicide rate per 100,000 inhabitants, in the mother's year of pregnancy. X'_{it} denote mothers, pregnancies, and newborn characteristics. The estimation also includes the variables d_m and d_t, which are the municipality and the birth cohort fixed effects, respectively. Finally, u_{imt} is the error term, and the standard errors are clustered at the municipality level.

Equation (3) identifies the causal effect of homicides on birth outcomes if – conditional on observable controls – the mothers in the same municipality have similar birth outcomes for reasons other than because of their differential exposure to homicide rates during pregnancy. The coefficient β_1 measures the average difference in newborn health outcomes due to changes in the municipality's homicide rate. The implicit assumption behind this identification strategy is that, after controlling for municipality and cohort fixed effects, household characteristics, and other relevant exogenous covariates, health outcomes should be similar across municipalities in the absence of violence.

The approach I adopt in this estimation closely follows the empirical strategy of Koppensteiner and Manacorda (2016), who examine the effect of violent crimes on newborns health in Brazil. These authors compare mothers who were exposed to a homicide during pregnancy to otherwise similar mothers residing in the same area, who were not exposed.

During versus post pregnancy homicides exposure

The second identification strategy is a difference-in-differences approach that compares the difference in health outcomes between newborns from mothers indirectly exposed or not exposed to a homicide during their pregnancy, versus an analogous difference between newborns born to mothers indirectly exposed or not exposed to a homicide within 9 months after birth. The sample of newborns considered in this analysis includes the newborns from mothers who were exposed to a homicide within 1 km (or 5 km) radius of their residence during pregnancy or within 9 months after delivery, from 2015 to 2017. Specifically, I estimate the following specification:

$$Y_{imt} = \beta_0 + \sum_{T=1}^{T=3} \beta_T \, T^{th} \, Homicide \; Exposure_{imt} + \beta_2 X'_{it} + d_m + d_t + u_{imt} \quad (4)$$

where $Y_{i,m,t}$ is the health outcome of newborn i, in the time cohort t, and municipality m. The variable $T^{th}\ HomicideExposure_{imt}$ is a dummy variable that takes the value of 1 if the mother experienced a homicide within km (or 5 km) during the T^{th} gestation trimester. d_m and d_t are the municipality and the birth cohort fixed effects, respectively. X'_{it} represents a vector of variables with the mother, pregnancy, and newborn characteristics. Standard errors are clustered at the municipality level. This specification allows me to analyze in which trimester of gestation maternal stress caused by the indirect exposure to a homicide affects newborn health. Finally, I cluster the standard errors at a municipality level in this estimation.

I complete the estimation of equation (4) with the inclusion of a variable that accounts for the mothers' exposure to homicides in the past in her neighborhood. The objective of this specification is to examine whether maternal stress related to the exposure to a homicide during the pregnancy is attenuated if she lives in a neighborhood that was exposed to other crimes in the past. Taking this into account, I estimate the following specification:

$$Y_{imt} = \beta_0 + \sum_{T=1}^{T=3} \beta_T \, T^{th} \, HomicideExposure_{imt} + \beta_2 Past\ Exposure_{im} + \beta_3 X'_{it} + \sum_{T=1}^{T=3} \theta_T \, T^{th} \, HomicideExposure_{imt} * Past\ Exposure_{im} + d_m + d_t + u_{imt} \quad (5)$$

The coefficient θ_T in equation (5) shows how the effect of a homicide occurring during the newborn's T^{th} trimester of gestation is attenuated, when the mother was previously exposed to other crimes.

This identification approach follows the estimation strategy used by Currie, Muller-Smith, and Rossin-Slater (2020) to analyze the effect of assaults on birth outcomes. In their paper, the authors examine the difference in birth outcomes of the mothers that report a direct assault in the nine months after conception and those who experience an assault within ten months after the estimated due date. Since, I estimate the impact of the environmental stress produced by homicides, the specification also includes the mothers' exposure to other crimes in the 5 years before pregnancy to capture a potential attenuation effect.

Maternal fixed effects

The third identification strategy compares the health outcomes of siblings born to the same mother that were exposed to different levels of environmental stress during their pregnancies. For this objective, I link the siblings of the data set using the mother identifiers. Specifically, I estimate the following fixed effects model:

$$Y_{ikmt} = \beta_0 + \sum_{T=1}^{T=3} \beta_T \, T^{th} \, HomicideExposure_{ikmt} + \beta_2 Past\ Exposure_{ikmt} +$$

$$\beta_3 X'_{ikt} + \sum_{T=1}^{T=3} \theta_T \, T^{th} \, HomicideExposure * Past\ Exposure_{ikmt} + d_k +$$

$$d_m + d_t + u_{ikmt} \quad (6)$$

where k refers to the mother's indicator. In this expression, $HomicideExposure_{ikmt}$ is a dummy variable that takes the value 1 for newborns exposed to homicides during the T^{th} gestation period. The vector of control variables X'_{ikt} includes a set of controls for the mothers and the children considered in the analysis and that are only time-variant characteristics (including birth order, and the number of siblings), and also three birth interval dummies: first birth, less than 12 months from previous birth, 12-24 months from previous birth, and 24-36 months from previous birth. Moreover, the equation (6) includes a birth cohort fixed effect d_t, a municipality fixed effect d_m, and a mother fixed effect d_k to account for newborns that have the same mother. As in equation (5), the coefficient θ_T of equation (6) shows whether the effect of the homicides occurring during the T^{th} trimester of gestation is moderated when the mother has been indirectly exposed to other crimes in the 5 years before gestation.[42] Finally, the standard errors are clustered at the mother level.

Controlling for maternal fixed effects, to examine the effect of an exogenous event on newborn health, has previously been used by Duque (2017), Guintella, La Mattina, and Quintana-Domeque (2019), Currie, Muller-Smith, and Rossin-Slater (2020) and Calzada, Gisbert, and Moscoso (2021). In their research, these authors compare the differences between sibling health outcomes. For instance, Duque (2017) uses this strategy to examine the differences in cognitive outcomes between siblings who were exposed to different levels of violence during each gestation stage. Currie, Muller-Smith, and Rossin-Slater (2020) use this strategy to compare health outcomes of newborns born to mothers who suffered an assault during one of their pregnancies but not in the other. In equation (6), I follow this approach to measure the effects of maternal stress produced when the mother was exposed to a homicide in her neighborhood during one pregnancy. Moreover, I interact the exposure variable with the mother's historical exposure to homicides, to examine whether the exposure to other homicides in the past attenuates maternal stress.

[42] Nearly 5% of the 490,000 newborns examined for the years 2015 to 2017 had a sibling born in the same period.

4.5 Results

4.5.1 Exposure to local violence

Table 4.2 presents the results of the estimation of equation (3) for the first identification strategy, which compares the birth weight of newborns who, during the pregnancy period, had different indirect exposures to homicides. Column (1) presents the results for the whole sample of newborns in the period 2010 to 2018 and shows that the municipality homicide rate has a negative and significant effect on newborn birth weight. Specifically, a one standard deviation (SD) increase in homicide rates leads to a 4.89 SD decrease in birth weight.[43] Columns (2) to (4) focus on newborns born to mothers living in municipalities with very few homicides (2 homicides per year maximum). This analysis enables me to test whether the effect of homicides is stronger in municipalities with very few homicides, where the mothers are less used to dealing with the psychological effects of this type of crime. These specifications show a negative but not significant effect of homicides on newborn birth weight.

Columns (5) to (8) repeat the previous analysis but restricting the sample to births with a normal delivery, as a C-section (very frequent in Ecuador) can modify the duration of the gestation period. The results for the complete sample in Column (5) reveal that the homicide rate leads to a 5.1 SD reduction in birth weight.[44] Furthermore, Column (6) analyzes the case of municipalities with very few homicides, and it shows that the homicide rate leads to a 13.93 SD decline in birth weight. The results do not show a statistically significant magnitude with respect to girls born through normal delivery. Column (8) focuses on newborn boys with normal delivery and finds that a 1 SD increase in exposure to homicide rates leads to a 15.58 SD deficit in birth weight. This is in line with the evidence suggesting that boys are at higher risks of negative health outcomes (Lawn et al., 2013). Moreover, recent evidence has shown that the biological conditions of newborn boys generate greater vulnerability to maternal stress during pregnancy than in the case of newborn girls (Walsh et al., 2019).

These findings show that higher homicide rates in the mothers' municipality generates maternal stress that reduces newborn birth weight. Interestingly, the birth weight deficit is higher in municipalities that have a low number of homicides per year. This result suggests that maternal stress may be related with the occurrence of unexpected crimes in the mothers' neighborhood. These results are in line with those of

[43] The back-of-the-envelope calculation reveals that the birth weight deficit is 4.5 grams, as the coefficient (-0.37) represents a unit increase in homicide rates, and the average homicide rates in Column (1) is 12.1 homicides per 100,000 inhabitants (12.1 x -0.37 = -4.5 g.).

[44] In terms of weight, the birth weight deficit is nearly 4.2 g (12 x -0.35).

Koppensteiner and Manacorda (2016) in Brazil, where the authors find that indirect exposure to violence leads to a 2-gram reduction in birth weight. These authors restrict the analysis to municipalities with up to 5,000 inhabitants.

One positive aspect of the previous analysis is that I have examined the effects of violence on newborn health using 1 million observations from 900 municipalities from 2010 to 2018. In spite of this, this estimation does not capture the fact that, even for mothers living in the same municipalities, there might be significant differences between the characteristics of the neighborhoods and exposures to violence. The unobservable characteristics of the mothers' neighborhood might be correlated with the homicide rates and also with newborn health outcomes. The next estimation aims to overcome this potential endogeneity problem by estimating a DID approach and using a more precise measure of exposure to violence.

4.5.2 Diff-in-diff analysis

Next, I present the results of the second identification strategy in which I compare the effects of being exposed or not exposed to homicides during pregnancy, relative to the analogous difference of being exposed within the 9 months following the birth of the newborns. For this analysis, I use the sample of births within the period 2015 to 2017, for which I have information on the mothers' home address, and I include all newborns whose mothers were exposed to a homicide during the pregnancy period, or during the 9 months after the birth of their newborn. Moreover, the $HomicideExposure_i$ variable defines whether or not the newborns were exposed to the maternal stress of homicides, using buffers of a 1-km (or 5-km) radius from the mothers' location.

Table 4.3 reports the results of the estimation of equation (4) when the outcome variable is the birth weight. The left panel shows the results including the full set of newborns, while the right panel includes the newborns from municipalities with very few homicides (two at most). Column (1) shows no effects of indirect exposure to homicides. Similar results are obtained in Column (2) when I consider the effect of exposure in each gestation trimester, and in Columns (3) and (4) when I consider municipalities with very few homicides. Nonetheless, Column (5) shows the effect on newborn girls in municipalities with a small number of homicides and finds that one standard deviation increase in exposure to homicides leads to an 8.13 SD decline in birth weight if the exposure happens during the first trimester of gestation.[45] Meanwhile, Column (6) suggests no statistically significant effects among newborn boys.[46]

I further analyze heterogeneity results among C-Section births and normal labor births in Tables 4.A4 and 4.A5 in the Appendix A since C-section births account for around 50% of total births in Ecuador (See Table 4.1). The objective of these tables is to provide further evidence of the different effects of exposure to homicides between these two groups, as previous studies have documented that stress is a significant factor related to unplanned C-section births (Ko, Lin, Chen, 2015).[47]

The analysis so far has shown that maternal stress produced by indirect exposure to homicides is stronger for newborns from municipalities with very few homicides, where mothers might be less used to this type of crime and emotionally more affected by each event. These findings are in line with the economic literature that analyzes the effect of exogenous shocks such as war, terrorist attacks, and conflicts (Camacho,

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45 Alternatively, the magnitude of a unit increase in the exposure dummy is equivalent to a birth weight deficit of around 20 grams.

46 These results are consistent when the exposure variable considers homicides occurring within a 5-km radius (See Table 4.A1 in the Appendix A). In this case, newborn girls exposed to homicides in their first gestation trimester have a negative coefficient, which suggests a birth weight deficit of 11.6 grams. Moreover, I test the result including newborns from municipalities with low numbers of homicides per year (five at most) in Table 4.A2 in Appendix A. I find that newborn girls that were exposed to homicides within 1-km in their first gestation trimester have a birth weight deficit of almost 15 grams (the coefficient is -14.9). In contrast, when newborn girls were exposed to homicides within 5-km in their first and second trimester of gestation, the birth weight deficit is nearly 7.8 and 8.2 grams, respectively.

47 In the context of Ecuador, I do not find that C-section births are positively affected by exposure to homicides per-se (see Table 4.A3 in the Appendix A). As such, the subsequent results between normal births and C-section births, are not driven by collinearity between indirect exposure to homicides and C-section births. Table 4.A4 and 4.A5 in Appendix A repeats the analysis focusing on newborns born by C-section and by normal labor, respectively. The left panel of Table 4.A4 shows the results including the full set of C-section births, while the right panel includes the C-section births from municipalities with very few events (two at most). Column (1) suggests no effects from exposure during the whole pregnancy, and Column (2) finds no effect when I analyze the effect in each gestation trimester. Columns (3)-(5) present the results for newborns from municipalities with very few homicides. In Column (3), the analysis for the whole sample finds a negative but not significant effect of homicides. But Column (4) shows that a SD unit increase in exposure to homicides in the first gestation trimester leads to a 11.35 SD reduction in birth weight. Moreover, Column (5) and (6) repeat the analyses by sex and show that a one SD increase in exposure to homicides, leads to a 20.33 SD deficit in the birth weight for newborn girls when the exposure occurred during their first gestation trimester. The back-of-the-envelope calculation for the results from Column (5) suggest that the magnitude of a unit increase in the exposure dummy is equivalent to a birth weight deficit of 48 grams. Table 4.A5 in Appendix A shows the results including normal delivery births. Overall, I find negative but not statistically significant effects between exposure in first trimester of gestation and birth weight.

2008; Minoiu and Shemyakina, 2014; Quintana-Domeque, Ródenas-Serrano, 2017; Tapsoba, 2020). These studies measure the potential exposure to stressful events and find that newborn and children's health outcomes deteriorate as exposure occurs in affected regions (or even in locations where violence does not occur).

To better capture the fact that intensive and continuous exposure to violent crimes might attenuate the impact of a homicide during gestation, I complete the estimation of equation (4) with the inclusion of the $Past\ Exposure_i$ variable. As explained in Section 4, this variable measures the homicide density for each mother's home address point in the 5 years before pregnancy. Therefore, equation (5) reflects whether maternal stress related to exposure to a homicide during pregnancy is reduced when the mother was previously exposed to other violent crimes.

Table 4.4 shows the results of the estimation of equation (5), which repeats the previous analysis, but it now controls for the mothers' previous exposure to homicides in their neighborhood. Columns (1) to (4) present the results for all the municipalities, while Columns (5) to (8) show the results from municipalities with a small number of homicides per year (two at most). I do not find an overall impact of exposure during the entire pregnancy (Column 1), or during any gestation trimester (Column 2). In Column (3), I estimate equation (5) for newborn girls and I find that one SD in exposure to homicides leads to a 4.23 SD decline in birth weight if the exposure happens during the first trimester of gestation.[48] Moreover, also in Column (3), I find that one SD increase in past exposure to homicides leads to a 6.14 SD increase in birth weight if newborn girls were exposed during the first trimester of gestation. This implies that the effect of a homicide during the first trimester of gestation is attenuated when the mother was previously exposed to other homicides. I also find a positive effect when newborn girls are exposed during the third gestation trimester, and a negative but not significant effect of past exposure to homicide when exposure occurs during the third trimester, which can be explained by the mitigation of the stress generated by violent crimes in later stages of pregnancy, as argued by Entringer et al. (2010). Indeed, the birth weight deficit caused by exposure during the first gestation trimester and the birth weight gains in the third trimester can be interpreted as an attenuation effect within the pregnancy period (Entringer et al., 2010). This result suggests that exposure to homicides is statistically significant during the first trimester of gestation. In terms of weight, the results of the Column (3) shows that a unit increase in the exposure dummy leads to birth weight deficit of nearly 8.6 grams, and the net effect is very close to a deficit of 5.1 grams when controlling for past exposure to violent crimes.

[48] The magnitude of a unit increase in the exposure dummy is equivalent to a birth weight deficit of 8.6 grams.

Column (7) in Table 4.4 repeats the estimation of equation (5) for municipalities with a low number of homicides per year. Focusing on the case of newborn girls, column (7) shows that a unit increase in exposure during the first trimester leads to a -31 coefficient, which is the deficit in birth weight in grams. In the same column, I do not find statistically significant effects of exposure during third trimester. Moreover, I find that past exposure to homicides causes a reduction in maternal stress generated by a homicide during pregnancy. A one SD increase in past exposure to homicides leads to a 7.73 SD increase in birth weight if the exposure happens during the first trimester of gestation.[49] Overall, the results in Column (7) suggest that the aggregated birth weight deficit is 29 grams when newborn girls are exposed during their first trimester of gestation. In spite of this, I do not find statistically significant results for newborn boys in terms either exposure or past exposure to homicides.

The analysis in Table 4.5 examines the differences in birth outcomes by type of birth. Newborns born by normal delivery are not found to be negatively affected by exposure to homicides once I control for past exposure to homicides. The right panel of Table 4.5 shows the estimates of equation (5) when I consider C-Section births. Column (5) shows that 1 SD increase in exposure leads to a 11.41 SD decrease in birth weight when the newborn girls were exposed during their first trimester of gestation.[50] This is in line with the literature that suggests that maternal stress leads to prematurity and C-Section births (Ko, Lin, Chen, 2015; Pun et al., 2019). In fact, I observe slightly higher prenatal care visits in the exposed-during-pregnancy group (6.49) than in the exposed-after-birth comparison group (6.47) as shown in Table 4.1. The results in Column (5) also show that a one SD increase in past exposure to homicides leads to a 14.8 SD increase in birth weight if the exposure happens during the first trimester of gestation. This implies that the effects on birth weight of the exposure to a homicide during the first gestational trimester is attenuated when the mother has been exposed to homicides before pregnancy. Overall, the results in Table 4.5 reveal a birth weight deficit of almost 10 grams for newborn girls born by C-Section whose exposure to homicides happened during first trimester of gestation.

Note that the previous results should be interpreted as a lower bound for the effect of crime on newborn health since the analysis does not account for the effect of maternal stress on miscarriages. In this respect, it is also important to mention that the medical literature has found biological differences[51] in the survival probability of

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[49] On average, past exposure in the newborn's location is to 4.04 homicides per square kilometer, in municipalities with very low numbers of homicides, which leads to almost 2-grams gains in birth weight.

[50] The magnitude of a unit increase in the exposure dummy is equivalent to a birth weight deficit of 23.14 grams.

[51] Bale (2016) shows that the male fetuses have a prolonged period of vulnerability because they are slower to mature than female fetuses. Also, the female placenta is found to have higher levels of genes that may confer protection and adaptability to survive than the male placenta.

newborn girls and boys because of maternal stress during pregnancy (Walsh et al., 2019). The literature has also shown that detrimental conditions during pregnancy increase the probability of spontaneous abortions, although with a smaller probability of miscarriages of girl fetuses (Byrne et al., 1987; Hobel et al., 1999; Zaren et al. 2000; Ghosh et al., 2007; Del Fabro et al., 2011; Pongou, 2013; Buckberry et al., 2014).

All in all, the results from this analysis show that exposure to homicides during pregnancy has detrimental effects on newborn health, compared to newborns who were exposed to a similar type of violence after delivery. This negative impact is stronger for newborn girls and for babies born by C-Section. Moreover, I have found evidence that mothers living in a neighborhood with frequent episodes of violence may be less emotionally impacted by homicides occurring during the pregnancy period than mothers who are less exposed. These findings are in line with very recent literature that explores the direct and indirect effects of violence on birth weight, and that uses similar approaches for causal inference (Koppensteiner and Manacorda, 2016; Currie, Muller-Smith, and Rossin-Slater, 2020). The former authors report that exposure to a local level of violence is far more significant in smaller municipalities, and their results suggest a higher effect in the case of female newborns. Moreover, in their analysis of the city of Fortaleza, where homicides are more frequent, the authors suggest that an additional homicide may have a smaller impact on health at birth than when the homicides are infrequent. Meanwhile, Currie, Muller-Smith, and Rossin-Slater (2020) show evidence on direct victimization and birth outcomes, by combining the administrative data on assaults and births. Their results suggest that an assault during pregnancy is associated with a statistically significant decrease in birthweight and an increased probability of low birth weight.

The previous analysis has considered a sample of mothers indirectly affected by homicides in their surroundings, before or after delivery. Yet, there are potentially unobservable characteristics that can define different stress levels for mothers in the treated and comparison group, even if they are similarly exposed to violence. Next, I consider a maternal fixed-effects estimation that allows to control for the mother's intrinsic and time-invariant characteristics.

4.5.3 Maternal fixed-effects strategy

The third identification strategy repeats the previous analysis but focusing on a sample of newborns born to the same mother but who were subject to different levels of indirect exposure to homicides during gestation. Specifically, I re-estimate the DID model of equation (6) with a sample of the mothers that gave birth to two or more children in the period 2015 to 2017. Similar to the previous analysis, the exposure variable consists of a dummy variable considering whether or not the newborns were exposed to the environmental stress produced by homicides, using buffers of 1-km from the mothers' location.

Table 4.6 presents the result of the estimation of the maternal fixed-effects model in equation (6) with the new sample. Column (1) shows a negative but not significant effect of exposure to homicides in the second and third gestation trimesters on birth weight. Similar results are found in Column 2 for newborn female siblings. Column (3) presents the results for newborn male siblings, showing that a one SD increase in the exposure to homicide leads to 54.3 SD decrease in birth weight when exposure to homicides occurs during the third trimester of gestation. In terms of weight, newborn boys have a birth weight deficit of around 111 grams for a one unit increase in the exposure to homicide dummy, when it occurs in their last gestation stage, relative to their male siblings exposed to a homicide in the months after birth.

Next, I explore the heterogeneity of the results for normal and C-section births. Table 4.7 shows the estimates of equation (6) considering the newborns' sex. Column (1) shows that the effect of exposure to homicides in each of the gestation trimesters are negative but not statistically significant. Column (2) shows similar results for newborn girls with a normal birth delivery. Column (3) presents the results for newborn boys born by normal delivery and I find that a one SD increase in exposure to homicides during the last gestation term leads to a 60.92 SD reduction in birth weight.[52] Moreover, a I find that one SD unit increase in exposure to other episodes of violence before pregnancy leads to a 130.43 SD reduction in birth weight, as well as a positive -attenuated- impact of exposure during the third gestation trimester if the mother has previously been exposed to violence (70.08 SD). Previous exposure to violence denotes how dangerous the neighborhood is, given the frequent episodes of crime. Living in an area with previous high exposure to crime has a negative effect per-se on birth weight.[53] Nevertheless, newborns gestated in these areas who were exposed during the last gestation term have an attenuated effect, since maternal stress to an additional homicide is marginal given the high level of crime in her neighborhood[54]. Overall, the results from this specification suggest a birth weight loss of almost 257 grams.

Columns (4) to (6) in Table 4.7 show a sample of newborns delivered by C-Section. Column (4) shows that a 1 SD increase in exposure to homicides leads to 65.4 SD decrease in birth weight when it occurs during the last stage of gestation; a 1 SD

[52] The magnitude of a unit increase in the exposure dummy is equivalent to a birth weight deficit of 126.9 grams.
[53] On average, the samples' past exposure to homicides is to 96.93 homicides per square kilometer, which can lead to a birth weight deficit of 168 grams (96.93 x -1.73).
[54] On average, past exposure to homicides for the sample that were exposed in their last gestational term is to 40.76 homicides per square kilometer, which can lead to a birth weight deficit of 37.5 grams (40.76 x -0.92).

increase in past exposure denotes a 63.8 SD reduction in birth weight when exposure during pregnancy occurs in the second trimester of gestation; and a 1 SD increase in past exposure causes a 53.8 increase in birth weight when exposure during pregnancy occurs in the third trimester of gestation. These results suggest that, controlling for the characteristics of the mother, municipality and birth cohort, exposure to homicides has stronger negative effects during the last stage of gestation for C-section births, and this effect is compensated when the mother has been exposed to violence in her neighborhood before the pregnancy. Columns (5) and (6) do not report a statistically significant different impact of exposure to homicides on birth weight between female and male siblings born by C-section. This means that the C-section results in Table 4.6 are not gender biased. In contrast, the normal birth results suggest a gender bias towards newborn boys as the most affected group from exposure to homicides.

Table 4.8 completes the previous analysis by presenting the effects of exposure to homicides on the length of gestation and on the 1st minute Apgar score. Column (1) shows a negative but not significant impact of exposure to homicides on the number of gestation weeks, when exposure occurs during the first and third trimester of gestation. Nevertheless, results in Column (2) show a reduction in the gestation length of newborn girls when exposure to homicide occurs during the second trimester of gestation (for a unit increase in exposure, gestation weeks reduces by -0.48 weeks, nearly 3 days and a half before the due date). Moreover, Column (3) shows that the gestation length of newborn boys shortens when exposure to homicide occurs during the last stage of pregnancy (-0.44 weeks, nearly 3 days before the expected date of birth). This effect is attenuated by almost a day when the mother was previously exposed to crime. Note that, according to the medical literature, in the last gestation term, newborns gain about 226 grams in a week (ACOG, 2018). Therefore, a reduction of 2 days in the gestation length would imply an average birth weight deficit of almost 65 grams.[55]

Columns (4) to (6) in Table 4.8 show the results for the 1st minute Apgar score. I find a negative but not significant impact of exposure to homicides on Apgar score, when exposure occurs during the second and third trimester of gestation. However, when comparing exposed versus non-exposed siblings of the same sex, I find a reduction in the Apgar score of newborn girls when exposure to homicide occurs during the last trimester of gestation (for a unit increase in exposure status, the Apgar score falls by almost 0.3, nearly a third of the scoring scale unit). Moreover, the Apgar score for newborn boys reduces when exposure to homicide occurs during the third gestation trimester (-0.25, which is a quarter of a scoring scale unit).

The results from this analysis show that exposure to homicides during pregnancy has detrimental effects on newborn health compared to their siblings who were exposed

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[55] On average, 226 grams per week would represent a daily birth weight gain of 32.3 grams.

to a similar type of violence in the months after delivery. In contrast to the previous results, the maternal fixed-effects estimation shows that newborn boys are more sensitive to exposure to homicides in their last gestational term. This empirical strategy measures the effect among live newborns, so the results are not subject to a potential miscarriage bias. Moreover, similar to the results of the previous identification strategies, I have found that mothers living in a neighborhood with frequent episodes of violence may be less emotionally impacted by homicides occurring during the pregnancy period.

In line with Currie, Muller-Smith, and Rossin-Slater (2020), the results of the maternal fixed-effects estimation shows that indirect exposure to violent crimes has significantly negative effects on health at birth. Although the effect size between direct assaults (Currie, Muller-Smith, and Rossin-Slater, 2020) and indirect exposure to homicides may differ, the results I find also suggest that maternal stress induced by the perception of homicides leads to a deficit in birth weight, a reduction in gestation length and a decrease in the 1st minute Apgar score. Moreover, I find that the estimated effect of exposure to homicide is reduced when the mother has been exposed to other episodes of violence before the pregnancy, which can reduce maternal stress. This result is consistent with the previous identification strategy, in which past exposure to homicides may attenuate the impact of the exposure during pregnancy. Similarly, Koppensteiner and Manacorda (2016) argued that historical exposure to a local level of crime plays a fundamental role in determining differences in maternal stress from an additional homicide.

4.5.4 Income and nutritional shocks as potential confounders

This section examines the role of income and nutritional shocks to explain health at birth (Almond, Currie, and Duque, 2018). It may be expected that violent crimes generate a shock in the neighborhood that affects the supply of food, income, and nutrition and/or affects other sorts of socio-economic aspects. In this respect, it is expected that exposure to income shocks due to violent crimes would be stronger in the case of newborns of mothers with a low socio-economic status (SES). While mothers with a high SES might have the means to compensate for an income shock, mothers from with a low SES are more likely to face budget constraints (Bozzoli and Quintana-Domeque, 2014; Almond, Currie, and Duque, 2018). In order to investigate income as a potential confounding effect, I closely follow the approach of Bozzoli and Quintana-Domeque (2014) to analyze whether the income channel explains (part of) the deficit in weight at birth when the mother is indirectly exposed to homicides.

The economic literature has shown that birth weight is sensitive to nutrition and income changes that occurs during the last gestational stage. For instance, Stein and Lumey (2000) analyze how the cohort of newborns exposed to the Dutch famine during their last gestation stage on average had a lower birth weight than the group of newborns exposed in their first gestational stage. Another example is the research on the food stamp program in the United States by Almond et al. (2011), in which the authors conclude that the cohort of newborns who were exposed to the food stamp program during their last gestational term were born with birth weight gains. Furthermore, Bozzoli and Quintana-Domeque (2014) find that nutritional shocks due to the Argentinian economic crisis had a significant effect during the last gestational term, while stress-to-crisis has an impact during the first trimester of gestation. Accordingly, next I examine whether the birth weight of newborns of mothers with a low SES are more affected than those of mother with a high SES by exposure to nutritional or income shocks due to violent crimes (homicides) in the third trimester of pregnancy.

In the absence of precise information on income, I consider the schooling education level as an alternative for income in a low-income country (Savanti and Patrinos, 2005; Bozzoli and Quintana-Domeque, 2014). Table 4.9 shows the heterogeneity analysis for the newborns of mothers with low levels of schooling (up to basic/primary school) and those born to mothers with high levels of education (secondary school or above). Column (1) shows that the potential income shock, which may be correlated to violent crime, significantly affects newborns of mothers with a low level of schooling education when exposure occurs in the second trimester of pregnancy. This is consistent with potential nutritional/income shocks affecting this group of mothers, but not mothers with a higher level of education. Moreover, the results in Column (2) suggest that newborns of mothers with higher education levels are negatively affected by maternal stress when exposure to violent crimes occurs in their first trimester of gestation, and not in their third trimester of gestation. Column (2) also shows that this group of newborns experience birth weight gains when exposure occurs during the last gestation term. This can be interpreted as an attenuation effect, as mothers with a higher education level may be able to mitigate the stress generated by violent crimes over the course of their pregnancy, as argued by Entringer et al. (2010).

The right-hand panel of Table 4.9 shows the effects of homicides in municipalities with very few cases of violent crimes, among newborns of mothers with a low level of schooling in Column (3) and those born to mothers with a high level of education in Column (4). I find that the potential income shock does not affect the newborns' birth weight when exposure to homicides occurs in the last gestational term. In particular, the results from Column (4) suggest that newborns born to mothers with higher levels of schooling have birth weight deficits when they were exposed in-utero to maternal stress due to homicides during their first gestational stage. Since these municipalities have low numbers of homicides, the results do not suggest any potential mitigation of exposure to additional homicides in the last gestational term, which confirms the aforementioned argument by Entringer et al. (2010).

These results suggest the existence of income or nutritional deficits caused by the occurrence of homicides close to the mothers' home. Mothers with a lower education level are more likely to be budget constrained and, therefore, they are more likely to be affected by income loss due to homicides. In contrast, the mothers with a higher education level are less likely to face budget constraints or suffer nutritional deficits.

Finally, I further examine heterogenous results taking the mothers' age as 24 years old, as this is the average the age of completion of a bachelor's degree in Ecuador. This assessment shows whether mothers below 24 years of age might have fewer opportunities to mitigate any income and nutritional shocks due to the occurrence of violent crimes. Column (1) in Table 4.10 reports that newborns of mothers aged less than 24 years old are not statistically affected by nutritional or income shocks when exposed during their last gestation term. In contrast, Column (2) reports a negative effect of homicides in mothers older than 24, when homicides occur during the first gestational term. Note that this effect is alleviated when the mother was exposed to violent crimes in the past. In spite of this, I do not find any statistically significant effect of exposure to violent crimes in municipalities with very low numbers of homicides, although there is a negative but not significant effect when exposure occurs during the first trimester of gestation.

4.6 Conclusions

This paper contributes to a growing body of economic, psychological, and medical literature that examines the effects of prenatal conditions and maternal stress on health at birth. Firstly, I provide new evidence of the causal relationship between the in-utero exposure of newborns to homicides at each stage of gestation and its impact on newborn health outcomes. Secondly, I propose new measurements of newborns' indirect exposure to crime, which captures the mothers' distance from the homicides during gestation and their exposure to other violent crimes in the past. Thirdly, I design three identification strategies to test for the impact of violence on health at birth.

The paper has used three different approaches to analyze the effect of indirect exposure to homicides on newborn health. Firstly, I develop a fixed effects estimation that compares the birth weight of newborns that were indirect exposed to different homicide rates in their municipalities during the pregnancy period, over the period 2010 to 2018. The second identification strategy consists of a DID estimation approach that analyzes the difference between being exposed or not exposed to a homicide during pregnancy, compared to the analogous difference of being exposed within the 9 months following the birth of the newborns, using the sample of newborns born in the period 2015 to 2017. Moreover, I test whether maternal stress generated by indirect exposure to a homicide during pregnancy can be attenuated when the mothers were previously exposed to other crimes. The third identification strategy controls for maternal fixed effects, and the estimation considers a sample of the newborns born to the same mother but who were subject to different levels of indirect exposure to homicides during gestation. As before, this estimation examines the effect of being exposed or not during pregnancy, relative to the siblings exposed or not exposed within the 9 months after birth.

The main result of the analysis in this paper is that maternal stress due to indirect exposure to homicides during pregnancy generates birth weight deficits, and these effects are attenuated when controlling for past exposure to violent crimes. The results reveal that newborns indirectly exposed to high levels of homicide rates have a birth weight deficit of 4.5 grams. Moreover, the effect becomes larger when I restrict the analysis to municipalities with very few homicides events (15 grams). The interpretation of these results is that maternal stress may be more sensitive to a homicide when community violence is infrequent, simulating a violent shock, which explains the fact that the effect size is larger when considering only municipalities that reported very few homicides, than the magnitude when looking at the full sample. The findings drawn from the second specification suggest that exposure to homicides during the first gestational stage generates a birth weight deficit of between 20 to 31 grams, compared to newborns whose mothers are exposed to crime post-pregnancy. The maternal fixed-effects estimation reveals that exposure to homicides during the last gestational term generates a birth weight deficit of between 111 to 257 grams, compared to siblings exposed to a homicide after birth. Moreover, I find that exposure to homicides in the last trimester of gestation leads to a reduction in gestation length, and a deficit in the Apgar score at the 1st minute. Furthermore, in the second and third empirical strategies, I find that the mothers' past exposure to homicides attenuates the stress induced by homicides that occur during the gestation period. Mothers who were indirectly exposed to violence in their neighborhood before the pregnancy are less affected by maternal stress in the event of a homicide during pregnancy. I find these results consistent with the hypothesis that violence affects birth outcomes through maternal stress, as homicides are more likely to induce stress when there are very few violent crimes, and they are relatively uncommon for the mother.

The results from these analyses are comparable in magnitude to those found in other analyses of the effects of large terrorist attacks in Spain (Quintana-Domeque and Ródenas-Serrano, 2017) and landmine explosions in Colombia (Camacho, 2008). The latter finds that birth weight is reduced by 9 grams when one landmine explosion occurs during early pregnancy. The former finds that an additional terrorist attack leads to a birth weight reduction of 0.7 grams, as well as computing that the effect of being exposed to terrorism results in a birth weight reduction of 42.12 grams. I analyze violent crime such as homicides and exclude other forms of more frequent violence. Although my estimates refer to Ecuador, these results could potentially be extended to other settings of violence.

Overall, this research examines one aspect of violent crimes that has received very little attention in the economic and medical research: the effects of indirect exposure to homicides during the gestational period. The results highlight the importance of establishing social and health policies targeted at addressing the stress and insecurity of the affected individuals. The government's efforts should aim to enhance community safety, counteract violent crimes, and offer prenatal controls and psychotherapy to safeguard the mental health of mothers exposed to violence during pregnancy. Moreover, policy interventions should include all women and newborns living with stress caused by violence stress, rather than just the direct victims of violence. Future research should examine the long-term consequences of prenatal exposure to homicides on child health and cognitive outcomes, as well as on maternal welfare. In this respect, research ought to examine the long-term benefits of public policy interventions on security and social services for direct and indirect victims of violence.

Tables of Results

Table 4.1 – Newborns and mothers characteristics

Variable	All newborns (2010-2018)	Newborns with geographic information (2015-2017)	Not exposed during pregnancy, exposed after pregnancy	Exposed during pregnancy, not exposed after pregnancy	Exposed during and after pregnancy	Diff (6)
	(1)	(2)	(3)	(4)	(5)	(4)-(3)
Birth weight	3,089.24	3,075.276	3,069.279	3,067.506	3,071.387	-1.795
	(0.4390)	(0.7194)	(2.0147)	(1.9307)	(1.3956)	(2.791)
Gestation Weeks	38.5432	38.5734	38.5629	38.5414	38.5369	-0.021**
	(0.0015)	(0.0025)	(0.0071)	(0.0067)	(0.0047)	(0.010)
Apgar score 1 minute	8.06	8.0620	8.0599	8.0426	7.9587	-0.017***
	(0.001)	(0.0013)	(0.0038)	(0.0036)	(0.0025)	(0.005)
Mother's age	25.8320	25.5575	25.6993	25.8342	25.6422	0.135***
	(0.0058)	(0.0094)	(0.0262)	(0.0251)	(0.0177)	(0.036)
Boy newborns	0.5114	0.5135	0.5110	0.5164	0.5135	0.005*
	(0.0004)	(0.0007)	(0.0020)	(0.0019)	(0.0014)	(0.003)
Mother's education Less than HS	0.2912	0.3192	0.2987	0.2928	0.2439	-0.006**
	(0.0004)	(0.0007)	(0.0018)	(0.0017)	(0.0012)	(0.003)
Local ethnic group "Montubio"	0.0327	0.0553	0.0487	0.0461	0.0211	-0.003**
	(0.0002)	(0.0003)	(0.0009)	(0.0008)	(0.0004)	(0.001)
Mestizo	0.9148	0.9035	0.9140	0.9160	0.9227	0.002
	(0.0002)	(0.0004)	(0.0011)	(0.0011)	(0.0007)	(0.002)
Normal birth	0.4971	0.5750	0.5737	0.5621	0.5328	-0.012***
	(0.0004)	(0.0007)	(0.0020)	(0.0019)	(0.0014)	(0.003)
C-Section birth	0.5029	0.4250	0.4263	0.4379	0.4672	0.012***
	(0.0004)	(0.0007)	(0.0020)	(0.0019)	(0.0014)	(0.003)
Non marital union	0.3627	0.2786	0.2929	0.2954	0.2640	0.002
	(0.0004)	(0.0006)	(0.0018)	(0.0017)	(0.0012)	(0.003)
Single	0.3102	0.3892	0.3915	0.3884	0.3812	-0.003
	(0.0004)	(0.0007)	(0.0020)	(0.0019)	(0.0013)	(0.003)
Married	0.2983	0.2817	0.2651	0.2630	0.3090	-0.002
	(0.0004)	(0.0006)	(0.0018)	(0.0017)	(0.0013)	(0.002)
Public hospital births	0.7630	0.9037	0.9019	0.9026	0.9094	0.001
	(0.0004)	(0.0004)	(0.0012)	(0.0011)	(0.0008)	(0.002)
Number of births	2.1313	2.1380	2.1160	2.1095	2.1140	-0.006
	(0.0011)	(0.0019)	(0.0051)	(0.0049)	(0.0034)	(0.007)
Number of children	2.1598	2.1666	2.1446	2.1395	2.1415	-0.005
	(0.0012)	(0.0019)	(0.0052)	(0.0050)	(0.0035)	(0.007)
Prenatal control	6.7390	6.4020	6.4699	6.4882	6.4282	0.018
	(0.0024)	(0.0036)	(0.0103)	(0.0098)	(0.0065)	(0.014)
Single birth	0.9855	0.9853	0.9854	0.9848	0.9854	-0.001
	(0.0001)	(0.0002)	(0.0005)	(0.0005)	(0.0003)	(0.001)
Observations	1,308,371	490,566	62,402	68,356	134,371	130,758

Note: Column (1) shows the summary statistics for the whole set of newborns from 2010 to 2018. Columns (2) to (5) shows the summary statistics for newborns with available information on mothers' residential addresses during pregnancy (from 2015 to 2017), and who were in-utero exposed to any homicide within 1-kilometer radius distance.

Table 4.2 – Homicides rates and newborns' health: Effects of exposure to local level of violence

	OLS fixed effects (Birth weight)							
	All municipalities	Municipalities with very few homicides' events (≤2 homicides per year)			All municipalities	Municipalities with very few homicides' events (≤2 homicides per year)		
	All newborns	All newborns	Girls	Boys	Normal Labor	Normal Labor	Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Homicide rate	-0.3745**	-0.7425	-1.0814	-0.4839	-0.3537*	-1.2055*	-1.0494	-1.3499*
	(0.1351)	(0.5685)	(0.5785)	(0.6947)	(0.1478)	(0.5850)	(0.6752)	(0.6630)
Mother's control	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	1,308,358	241,326	117,567	123,744	650,430	138,263	67,737	70,502
R2	0.0982	0.1048	0.1046	0.0970	0.0823	0.0992	0.1016	0.0943

Notes: Each column shows the results of the estimation of equation (3) on birth weight. The homicide rate variable reflects how the intensity in the number of homicides at the municipality level affects newborns birth weight. Columns (1) and (5) include the full sample of newborns from all the municipalities. Columns (2) to (4) and (6) to (8) restrict the analysis to the municipalities with very few numbers of homicides per year (2 maximum). The controls of child characteristics are indicators of single birth and sex (except for columns (3), (4), (7), and (8)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), prenatal controls, indicator of total number of children, indicator of total births, and indicator of type of birth (c-section or normal delivery) only for columns(1) to (4). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 909 in column (1), 708 in column (2), 692 in column (3), 694 in column (4), 902 in column (5), 701 in column (6), 679 in column (7), and 683 in column (8), excluding single observations in all columns. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4.3 – Effects of exposure to homicides during pregnancy on birth weight

	OLS fixed effects (Birth weight)					
	All municipalities		Municipalities with very few homicides' events (≤2 homicides per year)			
	All newborns		All Newborns		Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during pregnancy	1.9335 (2.7897)		-3.5360 (7.5093)			
Homicide exposure during 1st Trimester		0.8255 (2.6187)		-12.9898 (8.9713)	-20.0173** (10.1537)	-5.8402 (12.1168)
Homicide exposure during 2nd Trimester		0.1644 (2.2966)		6.3255 (8.1670)	4.4015 (12.1705)	7.5357 (10.0356)
Homicide exposure during 3rd Trimester		3.9249 (2.5460)		-3.4350 (8.4381)	11.0031 (9.8036)	-16.1507 (11.9630)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	264,955	264,955	30,199	30,199	14,575	15,588
R2	0.1019	0.1019	0.1284	0.1285	0.1391	0.1184

Notes: Each column shows the results of the estimation of equation (4) on birth weight. The homicide exposure dummy reflects the effect of the being indirectly exposed to homicides during the entire pregnancy and in their k^{th} gestation trimester. Columns (1) and (2) include the full sample and municipalities. Columns (3) to (6) restrict the analysis for municipalities where the number of homicides per year are very few (2 maximum). The controls of child characteristics are indicators of single birth (for all columns) and sex (except for the columns (5) and (6)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), prenatal controls, indicator of total number of children, indicator of total births and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 539 in column (1), 539 in column (2), 247 in column (3), 247 in column (4), 222 in column (5), and 223 in column (6) excluding single observations in all columns. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4.4 – Effects of exposure during pregnancy on birth weight: All municipalities versus municipalities with very few homicides

	OLS fixed effects (Birth weight)							
	All municipalities				Municipalities with very few homicides' events (≤2 homicides per year)			
	All newborns		Girls	Boys	All newborns		Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Homicide exposure during pregnancy	4.0974 (4.3201)				2.3918 (9.2142)			
Homicide exposure during 1st Trimester		-3.4367 (3.5422)	-8.6122* (4.4138)	1.5137 (5.0504)		-13.6159 (10.3208)	-31.0629** (12.4666)	2.6973 (12.4598)
Homicide exposure during 2nd Trimester		-1.8006 (3.2699)	-3.3409 (4.6925)	-0.0267 (4.5092)		17.0356 (10.7241)	10.4048 (16.2124)	21.0445* (11.6723)
Homicide exposure during 3rd Trimester		4.4923 (3.1067)	10.8256** (4.2536)	-1.3651 (4.5465)		-0.0840 (9.9456)	7.0328 (12.2166)	-7.6528 (13.6506)
Past exposure	0.0520 (0.0547)	-0.0145 (0.0402)	-0.0090 (0.0682)	-0.0178 (0.0425)	0.2217 (0.3680)	0.3325 (0.4405)	0.1927 (0.6968)	0.5768 (0.4749)
Past exposure x Homicide exposure during pregnancy	-0.0322 (0.0466)				-0.3443 (0.2636)			
Past exposure x Homicide exposure 1st Trimester		0.0382 (0.0298)	0.0638** (0.0284)	0.0134 (0.0414)		0.0771 (0.2365)	0.5422* (0.3272)	-0.3470 (0.3128)
Past exposure x Homicide exposure 2nd Trimester		0.0147 (0.0187)	0.0053 (0.0359)	0.0235 (0.0280)		-0.5738 (0.4395)	-0.4346 (0.5688)	-0.6467 (0.4394)
Past exposure x Homicide exposure 3rd Trimester		-0.0113 (0.0217)	-0.0371 (0.0347)	0.0120 (0.0298)		-0.1331 (0.2280)	0.1751 (0.3240)	-0.3450 (0.3174)
Mother's control	X	X	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X	X	X
Observations	264,955	264,955	128,830	136,068	30,199	30,199	14,575	15,588
R2	0.1019	0.1019	0.0996	0.0934	0.1284	0.1286	0.1393	0.1187

Notes: Each column shows the results of the estimation of equation (5) on birth weight. The homicide exposure dummies reflect the effect of the being indirectly exposed to homicides in their k^{th} gestation trimester. The past exposure variable reflects the sum of the homicides' densities at the mothers' residential address location. Columns (1) to (4) include the newborns from all the municipalities. Columns (5) to (8) include the sample from municipalities with very few numbers of homicides per year (2 homicides per year maximum). The controls of child characteristics are indicators of single birth (in all columns) and sex (except for columns (3), (4), (7), and (8)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), prenatal controls, indicator of total number of children, and an indicator of total births. Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 539 in column (1), 539 in column (2), 496 in column (3), 502 in column (4), 247 in column (5), 247 in column (6), 222 in column (7) and 223 in column (8) excluding single observations in all columns. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4.5 – Effects of exposure during pregnancy on birth weight: Type of birth delivery and gender

	OLS fixed effects (Birth weight)					
	All municipalities					
	Normal births			C-Section births		
	All	Girls	Boys	All	Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during 1st Trimester	-1.8058 (3.7275)	3.7564 (5.3508)	-6.1921 (5.6554)	-4.2131 (6.1751)	-23.1380*** (7.4963)	12.2909 (8.3130)
Homicide exposure during 2nd Trimester	-3.8150 (3.9807)	-2.3841 (4.8990)	-4.0968 (5.1155)	2.6071 (5.1844)	-1.6784 (9.2707)	6.9579 (7.8677)
Homicide exposure during 3rd Trimester	5.0438 (3.8400)	8.8246* (5.2860)	2.1079 (5.8789)	5.4371 (5.1885)	14.8654* (7.6129)	-3.1241 (7.7858)
Past exposure	-0.0366 (0.0309)	-0.0023 (0.0425)	-0.0604 (0.0416)	0.0251 (0.0747)	-0.0029 (0.1170)	0.0483 (0.0854)
Past exposure x Homicide exposure 1st Trimester	0.0264 (0.0217)	-0.0112 (0.0289)	0.0571* (0.0334)	0.0480 (0.0504)	0.1539*** (0.0523)	-0.0431 (0.0664)
Past exposure x Homicide exposure 2nd Trimester	0.0338 (0.0240)	0.0462* (0.0276)	0.0143 (0.0304)	-0.0148 (0.0309)	-0.0563 (0.0687)	0.0228 (0.0639)
Past exposure x Homicide exposure 3rd Trimester	-0.0121 (0.0232)	-0.0179 (0.0328)	-0.0072 (0.0388)	-0.0170 (0.0333)	-0.0644 (0.0659)	0.0242 (0.0463)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	145,675	71,442	74,160	119,227	57,321	61,848
R2	0.0874	0.0837	0.0813	0.1243	0.1240	0.1160

Notes: Each column shows the results of the estimation of equation (5) on birth weight. The homicide exposure dummies, and the past exposure variable are detailed in the footnote of Table 4.4. Columns (1) to (3) include the sample of normal births from all municipalities. Columns (4) to (6) include the sample of C-Section births from all municipalities. The controls of child characteristics are indicators of single birth (in all Columns) and sex (except for Columns (2), (3), (5), and (6)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), prenatal controls, an indicator of total number of children, and an indicator of total births. Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 511 in column (1), 459 in column (2), 467 in column (3), 487 in column (4), 439 in column (5), and 451 in column (6), excluding single observations in all columns. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4.6 – Maternal fixed effects estimation: Exposure to homicides by gender

	OLS fixed effects (Birth weight)		
	All Newborns	Girls	Boys
	(1)	(2)	(3)
Homicide exposure during 1st Trimester	11.2965 (26.2427)	5.6677 (50.5747)	39.2152 (58.4568)
Homicide exposure during 2nd Trimester	-2.0709 (27.0376)	-63.0781 (58.5456)	-44.0082 (55.3888)
Homicide exposure during 3rd Trimester	-28.0872 (27.5142)	76.1356 (52.3170)	-111.72* (59.4068)
Past exposure	-0.2280 (0.2855)	-0.1696 (0.6145)	-0.5004 (0.5592)
Past exposure x Homicide exposure 1st Trimester	-0.0538 (0.1954)	-0.1170 (0.3967)	-0.2970 (0.3944)
Past exposure x Homicide exposure 2nd Trimester	-0.0087 (0.1811)	0.4764 (0.3987)	0.3885 (0.3354)
Past exposure x Homicide exposure 3rd Trimester	0.1291 (0.1806)	-0.6488* (0.3344)	0.6074 (0.3937)
Mother's control	X	X	X
Month x Year F.E.	X	X	X
Municipality F.E.	X	X	X
Maternal F.E.	X	X	X
Observations	10,371	3,016	3,081
R2	0.8771	0.9174	0.9011

Notes: Each column is a separate regression of equation (6) on birth weight. The homicide exposure dummies, and the past exposure variable are detailed in the footnote of Table 4.4. The sample is limited to births by mothers who had more than one pregnancy registered during the period 2015 to 2017. Column (1) shows the results for the full sample, while Columns (2) and (3) estimate the results by gender. The control of child characteristic is an indicator of single birth (in all columns) and sex (except for Columns (2) and (3)). The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, in union), a dummy indicator of place of birth (public or private hospital), prenatal controls, indicator of total number of children, an indicator of total births, and the indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the mother level and are shown in parentheses. The clusters number are 5,149 in column (1); 1,498 in column (2); and 1,535 in column (3), excluding single observations in each column. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4.7 – Maternal fixed effects estimation: type of birth delivery

	OLS fixed effects (Birth weight)					
	Normal delivery			C-Section		
	All Newborns	Girls	Boys	All Newborns	Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during 1st Trimester	-0.4513	15.9094	0.6219	-39.0923	-16.1815	-58.7395
	(32.1971)	(76.3667)	(70.2194)	(51.9397)	(86.3218)	(114.4190)
Homicide exposure during 2nd Trimester	-13.5178	-49.6049	-36.8844	60.8714	-6.9986	-179.7533
	(32.9380)	(78.3048)	(65.6836)	(56.0786)	(134.5725)	(122.6431)
Homicide exposure during 3rd Trimester	-15.9158	107.9521	-126.9686*	-134.1641**	-22.8521	-187.6634
	(33.4457)	(77.4683)	(70.7091)	(55.5311)	(92.6576)	(123.1364)
Past exposure	-0.6527*	-0.0142	-1.7335**	-0.3120	-1.0049	0.9009
	(0.3797)	(1.0270)	(0.6868)	(0.5273)	(1.0167)	(1.2908)
Past exposure x Homicide exposure 1st Trimester	0.0205	0.0173	0.2709	0.2783	0.1707	-0.1800
	(0.2494)	(0.6893)	(0.4596)	(0.3594)	(0.6185)	(0.9564)
Past exposure x Homicide exposure 2nd Trimester	0.2332	0.4412	0.6618	-0.6634**	0.0636	0.2409
	(0.2240)	(0.6539)	(0.4088)	(0.3390)	(0.6937)	(0.6739)
Past exposure x Homicide exposure 3rd Trimester	0.3442	-0.6317	0.9140**	0.5640*	-0.1146	0.1812
	(0.2389)	(0.6167)	(0.4629)	(0.3246)	(0.5065)	(0.7829)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Maternal F.E.	X	X	X	X	X	X
Observations	4,056	985	1,046	5,482	1,810	1,763
R2	0.8415	0.8967	0.8921	0.9014	0.9330	0.9227

Notes: Each column is a separate regression of equation (6) on birth weight. The homicide exposure dummies, and the past exposure variable are detailed in the footnote of Table 4.4. The sample is defined in Table 4.6. Column (1) shows the results for all normal births, while Columns (2) and (3) estimate the results by gender for normal births. Column (4) shows the results for all C-section births, while Columns (5) and (6) estimate the results by gender for C-section births. The control of child characteristic is an indicator of single birth and sex. The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), an indicator of marital status (divorced, separated, widowed, married, single, in union), an indicator of place of birth (public or private hospital), prenatal controls, an indicator of total number of children, and an indicator of total births. Standard errors are clustered at the mother level and are shown in parentheses. The clusters number are 2,022 in column (1); 490 in column (2); 523 in column (3); 2,721 in column (4); 900 in column (5); and 878 in column (6), excluding single observations in each column. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4.8 – Maternal fixed effects estimation: Gestation weeks and 1st minute Apgar score by gender

	OLS fixed effects					
	Gestation weeks			Apgar score at the 1st minute		
	All Newborns	Girls	Boys	All Newborns	Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during 1st Trimester	-0.1731	-0.3729	0.1468	0.0279	0.1066	0.2309
	(0.1139)	(0.2419)	(0.2305)	(0.0667)	(0.1314)	(0.1524)
Homicide exposure during 2nd Trimester	0.0325	-0.4840**	0.0730	-0.0190	-0.0796	-0.0654
	(0.1155)	(0.2454)	(0.2180)	(0.0640)	(0.1559)	(0.1420)
Homicide exposure during 3rd Trimester	-0.1567	-0.1993	-0.4433**	-0.0881	-0.2917**	-0.2521*
	(0.1154)	(0.2125)	(0.2218)	(0.0665)	(0.1314)	(0.1473)
Past exposure	-0.0018	-0.0023	-0.0023	0.0000	0.0008	-0.0004
	(0.0012)	(0.0028)	(0.0023)	(0.0007)	(0.0014)	(0.0014)
Past exposure x Homicide exposure 1st Trimester	0.0013	0.0011	0.0003	-0.0001	-0.0009	-0.0005
	(0.0008)	(0.0018)	(0.0016)	(0.0005)	(0.0008)	(0.0010)
Past exposure x Homicide exposure 2nd Trimester	0.0000	0.0025	0.0002	-0.0003	-0.0011	0.0009
	(0.0007)	(0.0017)	(0.0012)	(0.0004)	(0.0009)	(0.0009)
Past exposure x Homicide exposure 3rd Trimester	0.0005	-0.0002	0.0023*	0.0006	0.0010	0.0010
	(0.0007)	(0.0016)	(0.0014)	(0.0005)	(0.0009)	(0.0008)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Maternal F.E.	X	X	X	X	X	X
Observations	10,371	3,016	3,081	10,371	3,016	3,081
R2	0.8846	0.9385	0.9309	0.7142	0.7888	0.7573

Notes: Each column is a separate regression of equation (6) on gestation length (in weeks) in the left-hand side panel (Columns (1) to (3)), and on the 1st minute Apgar score in the right-hand side panel (Columns (4) to (6)). The homicide exposure dummies, and the past exposure variable are detailed in the footnote of Table 4.4. The sample is defined in Table 4.6. Columns (1) and (4) show the results for the full sample, while Columns (2), (3), (5) and (6) estimate the results by gender. The control of child characteristic is an indicator of single birth (in all Columns) and sex (except for Columns (2), (3), (5), and (6)). The controls of the maternal characteristics are time variant: mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, in union), dummy indicator of place of birth (public or private hospital), prenatal controls, an indicator of total number of children, an indicator of total births, and an indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the mother level and are shown in parentheses. The clusters number are 5,149 in column (1); 1,498 in column (2), 1,535 in column (3); 5,149 in column (4); 1,498 in column (5), 1,535 in column (6), excluding single observations in all columns. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4.9 – Effects of exposure to homicides during pregnancy on birth weight: Education

	OLS fixed effects (Birth weight)			
	All municipalities		Municipalities with very few homicides' events (≤2 homicides per year)	
	Low Schooling Education	High Schooling Education	Low Schooling Education	High Schooling Education
	(1)	(2)	(3)	(4)
Homicide exposure during 1st Trimester	5.4105 (6.5956)	-6.5450* (3.8942)	2.9584 (20.8484)	-21.1641* (11.1994)
Homicide exposure during 2nd Trimester	-13.8708** (6.1152)	3.5035 (3.3923)	29.3122 (19.1492)	13.0646 (11.6861)
Homicide exposure during 3rd Trimester	-0.5898 (6.4340)	7.3161* (3.9719)	4.0960 (18.5131)	0.5033 (11.3204)
Past exposure	-0.2113* (0.1229)	0.0425 (0.0363)	-0.2797 (0.9053)	0.4485 (0.4816)
Past exposure x Homicide exposure 1st Trimester	0.0346 (0.0651)	0.0394 (0.0274)	-0.0960 (0.3315)	0.1736 (0.3250)
Past exposure x Homicide exposure 2nd Trimester	0.1009** (0.0438)	-0.0203 (0.0182)	-0.7940* (0.4421)	-0.5317 (0.4897)
Past exposure x Homicide exposure 3rd Trimester	0.0039 (0.0428)	-0.0253 (0.0248)	-0.3603 (0.3648)	-0.1021 (0.2672)
Mother's control	X	X	X	X
Municipality F.E.	X	X	X	X
Month x Year F.E.	X	X	X	X
Observations	71,329	193,564	10,450	19,706
R2	0.1092	0.1028	0.1386	0.1363

Notes: Each Column shows the results of the estimation of equation (5) on birth weight. The homicide exposure dummies reflect the effect of the being indirectly exposed to homicides in their k^{th} gestation trimester. Columns (1) and (2) include the full sample of newborns by level of schooling education, respectively. Columns (3) and (4) restrict the analysis for municipalities where the number of homicides per year are very few (2 homicides per year as a maximum). The controls of child characteristics are indicators of single birth (in all columns) and sex. The controls of maternal characteristics are mother's age, a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), indicator of total number of children, an indicator of total births, C-section dummy, and prenatal controls. Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 485 in column (1), 508 in column (2), 209 in column (3), and 230 in column (4), excluding single observations in all columns. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4.10 – Effects of exposure to homicides during pregnancy on birth weight: Mother's age

	OLS fixed effects (Birth weight)			
	All municipalities		Municipalities with very few homicides' events (≤2 homicides per year)	
	24 years younger	24 years older	24 years younger	24 years older
	(1)	(2)	(3)	(4)
Homicide exposure during 1st Trimester	3.2788 (4.8068)	-8.9426* (4.5912)	-0.3654 (12.7269)	-21.7686 (16.9233)
Homicide exposure during 2nd Trimester	1.6302 (4.5329)	-4.3306 (4.4704)	20.7453 (14.4810)	12.7755 (13.8658)
Homicide exposure during 3rd Trimester	0.6722 (4.5095)	6.6821 (4.6102)	6.3336 (14.0042)	-5.2831 (14.7937)
Past exposure	0.0218 (0.0515)	-0.0412 (0.0479)	0.5074 (0.5100)	0.2805 (0.7223)
Past exposure x Homicide exposure 1st Trimester	-0.0051 (0.0473)	0.0743** (0.0315)	-0.0176 (0.3108)	0.0677 (0.3638)
Past exposure x Homicide exposure 2nd Trimester	0.0069 (0.0246)	0.0216 (0.0275)	-0.4531 (0.3818)	-0.6715 (0.5690)
Past exposure x Homicide exposure 3rd Trimester	0.0057 (0.0465)	-0.0225 (0.0257)	-0.2398 (0.3091)	-0.0032 (0.3253)
Mother's control	X	X	X	X
Municipality F.E.	X	X	X	X
Month x Year F.E.	X	X	X	X
Observations	113,023	151,871	13,674	16,482
R2	0.0951	0.1050	0.1332	0.1357

Notes: Each column shows the results of the estimation of equation (5) on birth weight. The homicide exposure dummies reflect the effect of the being indirectly exposed to homicides in their k^{th} gestation trimester. Columns (1) and (2) include the full sample of newborns by age group, respectively. Columns (3) and (4) restrict the analysis for municipalities where the number of homicides per year are very few (2 maximum). The controls of child characteristics are indicators of single birth (in all columns) and sex. The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), indicator of total number of children, an indicator of total births, and prenatal controls. Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 491 in column (1), 504 in column (2), 220 in column (3), and 220 in column (4), excluding single observations in all columns. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Appendix A – Robustness

Table 4.A1 – Effects of exposure to homicides during pregnancy on birth weight: Exposure at 5-kilometer distance radius

	OLS fixed effects (Birth weight)					
	All municipalities		Municipalities with very few homicides' events (≤2 homicides per year)			
	All newborns		All Newborns		Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during pregnancy	1.5532 (4.0560)		8.3486 (7.1415)			
Homicide exposure during 1st Trimester		-0.6885 (2.5766)		-1.9213 (5.7593)	-11.6089* (6.6042)	6.4830 (7.0760)
Homicide exposure during 2nd Trimester		2.6700 (2.4542)		6.7899 (5.3894)	-6.6416 (7.5235)	18.9064*** (6.1939)
Homicide exposure during 3rd Trimester		3.0787 (2.5251)		7.5018 (5.2662)	7.3183 (7.0439)	6.9115 (7.1499)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	398,687	398,687	61,936	61,936	29,939	31,974
R2	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045

Notes: Each column shows the results of the estimation of equation (4) on birth weight. The homicide exposure dummies reflect the effect of the being indirectly exposed to homicides during the entire pregnancy and in their k^{th} gestation trimester, that occurs within 5Km radius buffer from mothers' location. Columns (1) and (2) include the full sample and municipalities. Columns (3) to (6) restrict the analysis for municipalities where the number of homicides per year are very few (2 maximum). The controls of child characteristics are indicators of single birth (for all columns) and sex (except for the Columns (5) and (6)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), prenatal controls, indicator of total number of children, indicator of total births and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 862 in column (1), 862 in column (2), 402 in column (3), 402 in column (4), 387 in column (5), and 383 in column (6) excluding single observations in all columns. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4.A2 – Effects of exposure to homicides during pregnancy on birth weight: Municipalities with few homicides (≤5 homicides per year)

	OLS fixed effects (Birth weight)					
	Exposure buffer at 1 Kilometer Distance radius			Exposure buffer at 5 Kilometer Distance radius		
	All Newborns	Girls	Boys	All Newborns	Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during 1st Trimester	-4.3812	-14.4917**	5.8158	-1.2480	-7.8274*	5.1640
	(6.0398)	(7.3216)	(7.9563)	(3.7601)	(4.2470)	(5.0097)
Homicide exposure during 2nd Trimester	-1.0174	-4.7401	2.9622	2.2294	-8.2812*	11.9048**
	(6.3375)	(8.4417)	(7.4448)	(3.7402)	(4.7162)	(4.8465)
Homicide exposure during 3rd Trimester	3.5975	4.9497	2.4418	2.9319	2.1123	3.2481
	(5.5694)	(6.5153)	(8.1930)	(3.6546)	(4.8252)	(4.9424)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	58,722	28,479	30,202	116,227	56,506	59,700
R2	0.1193	0.1226	0.1108	0.1180	0.1188	0.1097

Notes: Each column shows the results of the estimation of equation (4) on birth weight. The homicide exposure dummies reflect the effect of the being indirectly exposed to homicides during the entire pregnancy and in their k^{th} gestation trimester. Columns (1) to (3) uses the exposure to homicides that occurs within 1Km distance buffer from the mother's location, while Columns (4) to (6) use the exposure to homicides that occurs within 5Km distance buffer from the mothers' location. The controls of child characteristics are indicators of single birth (for all columns) and sex (except for the Columns (2), (3), (5) and (6)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), prenatal controls, indicator of total number of children, indicator of total births and indicator of type of birth (c-section or normal delivery). Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 325 in column (1), 296 in column (2), 299 in column (3), 480 in column (4), 466 in column (5), and 461 in column (6) excluding single observations in all columns. Significance levels: $^{*} p < 0.1$, $^{**} p < 0.05$, $^{***} p < 0.01$.

Table 4.A3 – Effects of exposure to homicides during pregnancy on C-section

	OLS fixed effects (C-Section outcome)					
	All municipalities			Municipalities with very few homicides' events (≤2 homicides per year)		
	All Newborns	Female	Male	All Newborns	Female	Male
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during 1st Trimester	-0.0020 (0.0054)	-0.0031 (0.0072)	-0.0011 (0.0056)	0.0027 (0.0112)	0.0167 (0.0137)	-0.0102 (0.0153)
Homicide exposure during 2nd Trimester	-0.0127*** (0.0042)	-0.0152*** (0.0052)	-0.0102** (0.0051)	-0.0013 (0.0097)	0.0139 (0.0122)	-0.0125 (0.0134)
Homicide exposure during 3rd Trimester	-0.0013 (0.0040)	0.0022 (0.0049)	-0.0050 (0.0057)	-0.0090 (0.0094)	0.0176 (0.0139)	-0.0335** (0.0137)
Past exposure	-0.0001* (0.0000)	-0.0001 (0.0001)	-0.0001** (0.0000)	-0.0002 (0.0005)	0.0007 (0.0006)	-0.0010 (0.0007)
Past exposure x Homicide exposure 1st Trimester	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0005 (0.0004)	0.0006 (0.0004)	0.0005 (0.0004)
Past exposure x Homicide exposure 2nd Trimester	0.0001** (0.0000)	0.0001** (0.0000)	0.0000 (0.0000)	-0.0001 (0.0002)	-0.0009*** (0.0003)	0.0006** (0.0003)
Past exposure x Homicide exposure 3rd Trimester	0.0000 (0.0000)	-0.0000 (0.0000)	0.0001 (0.0000)	-0.0000 (0.0002)	-0.0007 (0.0005)	0.0005 (0.0003)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	264,955	128,830	136,068	30,199	14,575	15,588
R2	0.1136	0.1160	0.1143	0.1319	0.1406	0.1383

Notes: Each column shows the results of the estimation of equation (5) on C-section. The homicide exposure dummies reflect the effect of the being indirectly exposed to homicides in their k^{th} gestation trimester. Columns (1), (2) and (3) include the full sample of newborns. Columns (4) to (6) restrict the analysis for municipalities where the number of homicides per year are very few (2 maximum). The controls of child characteristics are indicators of single birth (in all columns) and sex. The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), indicator of total number of children, an indicator of total births, and prenatal controls. Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 539 in column (1), 496 in column (2), 502 in column (3), 247 in column (4), 222 in column (5), and 223 in column (6), excluding single observations in all columns. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 4.A4 – Effects of exposure to homicides during pregnancy on birth weight: C-Section births

	OLS fixed effects (Birth weight)					
	All municipalities		Municipalities with very few homicides' events (≤2 homicides per year)			
	C-Section births		C-Section births		Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during pregnancy	4.6402 (4.2784)		-4.2336 (16.1082)			
Homicide exposure during 1st Trimester		1.4390 (3.7745)		-27.0083* (15.4697)	-48.0346** (23.2389)	-9.0301 (17.8168)
Homicide exposure during 2nd Trimester		1.8218 (3.0499)		13.3332 (14.7857)	0.7973 (21.8569)	23.3824 (16.4393)
Homicide exposure during 3rd Trimester		4.4593 (3.6804)		-4.1101 (16.0893)	25.4427 (19.5347)	-37.7786 (22.9595)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	119,227	119,227	10,902	10,902	5,187	5,667
R2	0.1242	0.1242	0.1708	0.1713	0.1895	0.1646

Notes: Each column shows the results of the estimation of equation (4) on birth weight, for C-Section births. The homicide exposure dummies, and the past exposure variable are detailed in the footnote of Table 4.4. Columns (1) and (2) include the full sample of C-Section births. Columns (3) to (6) restrict the analysis for municipalities where the number of homicides per year are very few (2 maximum). The controls of child characteristics are indicators of single birth (in all columns) and sex (except for Columns (5) and (6)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), dummy indicator of place of birth (public or private hospital), prenatal controls, indicator of total number of children, and an indicator of total births. Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 487 in column (1), 487 in column (2), 214 in column (3), 214 in column (4), 179 in column (5), and 185 in column (6), excluding single observations in all columns. Significance levels: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 4.A5 – Effects of exposure to homicides during pregnancy on birth weight: Normal births

	OLS fixed effects (Birth weight)					
	All municipalities		Municipalities with very few homicides' events (≤2 homicides per year)			
	Normal delivery births		Normal delivery births		Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
Homicide exposure during pregnancy	1.2766 (3.0994)		-2.7249 (7.4847)			
Homicide exposure during 1st Trimester		0.9426 (2.9772)		-2.9157 (9.3389)	-2.5314 (11.2672)	0.0972 (14.0725)
Homicide exposure during 2nd Trimester		-0.2883 (3.0641)		1.8713 (8.4210)	4.9501 (12.4802)	1.4174 (12.3258)
Homicide exposure during 3rd Trimester		4.1758 (2.7757)		-1.1910 (9.5981)	0.9254 (11.7294)	-1.7730 (14.2444)
Mother's control	X	X	X	X	X	X
Month x Year F.E.	X	X	X	X	X	X
Municipality F.E.	X	X	X	X	X	X
Observations	145,675	145,675	19,266	19,266	9,340	9,870
R2	0.0873	0.0874	0.1089	0.1089	0.1163	0.1077

Notes: Each column shows the results of the estimation of equation (4) on birth weight, for normal delivery births. The homicide exposure dummies reflect the effect of the being indirectly exposed to homicides in their k^{th} gestation trimester. Columns (1) and (2) include the full sample of C-Section births. Columns (3) to (6) restrict the analysis for municipalities where the number of homicides per year are very few (2 maximum). The controls of child characteristics are indicators of single birth (in all Columns) and sex (except for Columns (5) and (6)). The controls of maternal characteristics are mother's age, maternal education dummy (less than high school and no diploma, equal to or higher than high school), a dummy indicator of marital status (divorced, separated, widowed, married, single, civil union), ethnic group (*mestizo, Montubio*, white, Afro-Ecuadorian, indigenous, other), prenatal controls, dummy indicator of place of birth (public or private hospital), indicator of total number of children, and an indicator of total births. Standard errors are clustered at the municipality level and are shown in parentheses. The clusters number are 511 in column (1), 511 in column (2), 231 in column (3), 231 in column (4), 196 in column (5), and 199 in column (6), excluding single observations in all columns. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

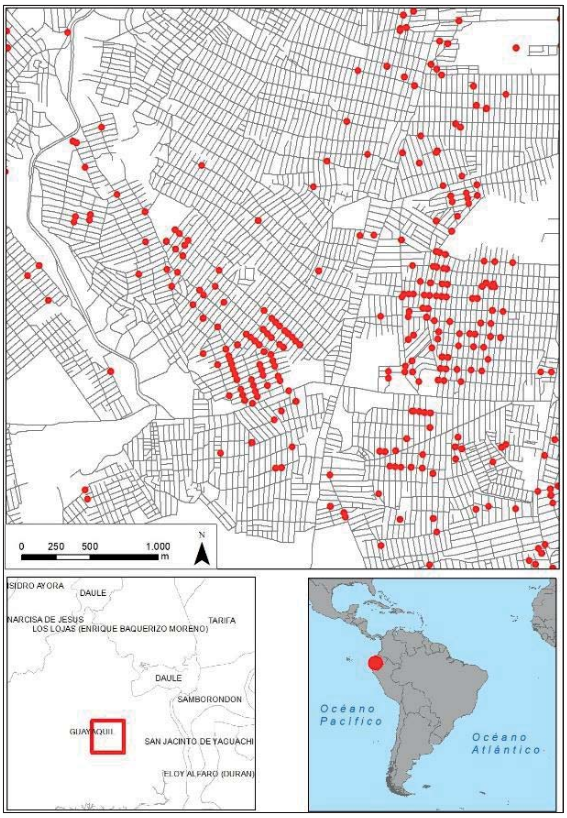
Appendix B – Methodology used to construct the exposure measures.

This section explains the methodology used to obtain: (1) the exposure dummy to a homicide within a 1-kilometer radius during versus post pregnancy; and (2) the prevalence or homicide density at the location of the mothers' household. QGIS software is used to compute these measures.

Exposure dummy. To identify the mothers exposed to a homicide, I first convert the alphanumeric table containing the postal addresses of the mothers into spatial information. I use the Google Maps API and successfully geolocate the residences of 495,887 newborns out of a total of 955,941 for the period 2015 to 2017 (Figure 4.B1). I compute a 1-kilometer radius buffer from the mother's residence. To do this, I use the *Buffer* tool on QGIS. As a result, a new *polygon* layer is generated with the information of each newborn (Figure 4.B2). Next, I use the *Join attributes by location* tool to combine multiple homicides to the respective buffer polygon to compute. The resulting output layer contains the newborn's identifier and date of birth, and the date of the homicide, which I use to determine the group of mothers indirectly exposed to a homicide during their pregnancy, and the comparison group of mothers indirectly exposed to a homicide during the 9 months following the newborns' birth.

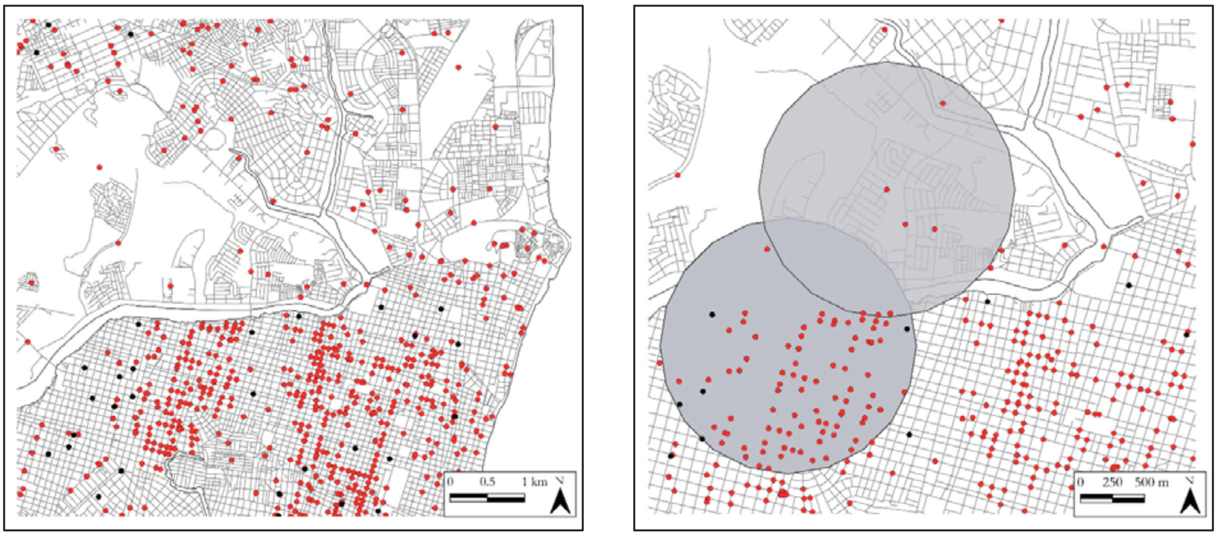
Figure 4.B1 – Alphanumeric data of newborns (left) and spatial information of addresses (right)

ID	Street address
260444	Batallon YY y la Y
405444	Vacas Galindo, YY entre YY y YY
179444	Sedalana, la YY y YY
471444	Alborada, YY y la YY



Source: Author's elaboration. Data from the newborns' register and the geographic street map.

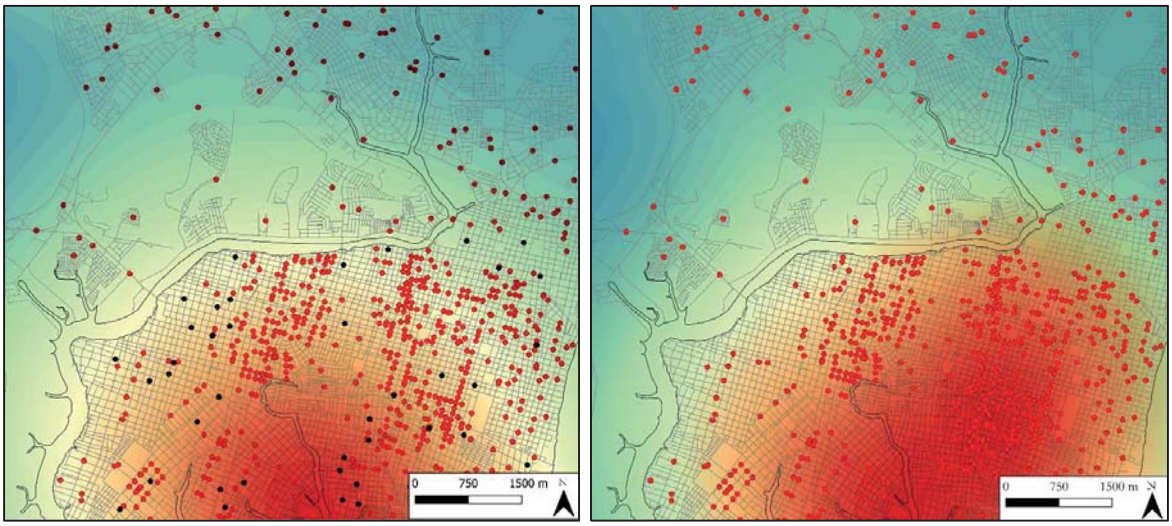
Figure 4.B2 – Buffer analysis and homicides overlap.



Note: Mothers' home address is represented by red dots, and the coordinates where homicides occurred are shown as black dots. As an illustrative example, the left-hand side figure shows the distribution of newborns (mothers' home addresses) in two neighborhoods of the same city, one without any homicides and the other exposed to many homicides. The right-hand side figure illustrates how the 1-kilometer radius buffer is drawn for two mothers (this process is performed for the full set of newborns).
Source: Author's elaboration. Data from the newborns and homicides registers.

Homicide density and exposure. I compute the kernel density function of each homicide point using the *heatmap (kernel density estimation)* tool in QGIS. I set a homicide kernel radius of 5 kilometers, and the kernel shape follows the standard *quartic* function (Figure 4.B3). I repeat this process for homicides that occurred during the last 5 years prior to the year of birth of the newborn. These heatmaps are generated with a pixel size of 25 meters x 25 meters. Once the heatmaps are generated, I use the *point sampling tool* in QGIS to extract the density values that coincide at each home address point. When this process is completed, the resulting newborn layer offers 6 new columns that compute the homicides densities in each year from birth date up to 5 years before birth.

Figure 4.B3 – Homicides heatmap (kernel density estimation)



Note: Based on the aforementioned illustrative example on Figure 4.B2, the left-hand side figure shows the homicide heatmap for a single year to visualize its distribution across space (5-kilometer buffer). The right-hand side figure shows the accumulated densities of year of birth and the 5 years prior to the birth.
Source: Author's elaboration, data from the newborns and homicides registers.

5 Chapter 5 – Final remarks

This PhD thesis studies three very relevant topics for public policies on development economics: health at birth and women victimization. In regard with the health at birth, I examine two recently explored -yet not vastly evidenced- aspects such as pesticides air pollution and maternal stress from violent crimes. In regard with the women victimization, I examine how legal reform to protect women is adversely associated with a raise on female homicide rates, implying a male backlash effect.

While aerial pesticide fumigation plays a key role in the agriculture industry, its massive and uncontrolled use is causing important health problems, as demonstrated in the second chapter of this PhD thesis. This chapter examines the causal relationship between newborns' in-utero exposure to pesticides and adverse health outcomes. In order to do this, we combine precise information on mother's residence during pregnancy, the perimeter of banana plantations and the volume and frequency of pesticide use in Ecuador, to create an individual measure of newborns' exposure to pesticides. We use this measure to implement three independent identification strategies to address the endogeneity of exposure to aerial fumigations. First, we consider a difference-in-differences strategy that exploits seasonal variations in the use of pesticides across provinces. Second, we estimate a difference-in-differences model that considers geographical variations in the use of pesticides across comparable crops. Third, and finally, we estimate a maternal fixed effects model to examine the effect of pesticides on siblings who had a different residence during gestation and who were exposed to different levels of fumigations. Our first empirical model shows that newborns exposed to pesticides, when their first gestational trimester coincides with the periods of intensive fumigations of the plantations, have a birth weight reduction of between 38 and 89 grams. Moreover, exposure to pesticides increases the likelihood of low birth weight and low Apgar score at first minute. The second model finds that newborns exposed to fumigated banana plantations have a birth weight deficit of between 29 and 76 grams, when compared to those exposed to other fumigated crops. Finally, the maternal fixed effect model show that girl newborns exposed to pesticides have a birth weight deficit of 346 grams when compared to non-exposed siblings.

We believe that this research can help to improve the design of public policies regarding fumigation practices in different plantations across the world and can be used to enhance pregnancy protocols in affected regions. Our conclusions reinforce the argument that is necessary to modify the use of agrochemicals in agriculture and to increase the protection for neighboring populations and the plantation workers. We have shown that in Ecuador, aerial fumigations have a very relevant impact on the health of newborns born in close proximity to the banana plantations. Our results highlight the urgency of enforcing and reviewing the protection distances established in the country's legislation in 2012 and 2015, to safeguard the health of the population living near the plantations.

In the third chapter of this PhD thesis, I study whether women empowerment and the toughening of the laws on femicides can generate a retaliation effect that temporary increases female homicides. Using a panel of 2167 solved female homicides in Ecuador from 2010 to 2020, I first analyze the characteristics and trends of female gender-violence victims (N=1711) and I compare them with the evolution of other-violence victims (N=456). Second, I analyze the effects of a reform of the penal code introduced in 2014 that modified the consideration of gender violence and increased the penalty for femicides. I exploit the fact that women empowerment and the enforcement of the law was not homogeneous across municipalities to test whether these policies were associated with a backlash effect that increased female homicide rates. My analysis finds an increment in the gender-violence rates in municipalities that enforced the introduction of the new femicide penalty type, and in municipalities exhibiting higher levels of women empowerment. Specifically, I obtain that in municipalities that introduced the new femicide type and with an increased level of women empowerment, there was an increase of gender-violence rates of 0.27 SD, relative to those that experienced gender-violence but not enforced the new femicide type.

The results of the paper show that, in Ecuador, the strategy to avoid future gender-violence victims with the penalization of female homicides might have temporarily created a retaliation effect. The findings of this paper suggest that enforcing the femicide penalty, accompanied with women empowerment, has been associated with a raise in the female homicides and the gender-violence rates, due to the male backlash effect. These results represent an evidence of the retaliation effect hypothesis that consider that gender equality policies and legislation reforms to toughening the penalties for femicides can generate (at least temporarily) an increase of gender violence. Future research should target the identification of risk and protective factors, to prevent female homicides, and also to evaluate social services outcomes on the interventions and support to the women who suffered assaults.

The fourth chapter of this PhD thesis studies mothers' indirect exposure to homicides on newborns' health outcomes. To do so, I combine two datasets that accounts for mothers' residential address during pregnancy and the coordinates of all homicides occurred in Ecuador in the period 2015-17. To solve for endogeneity to crime exposure, I use three empirical strategies. First, I estimate the difference in birth weight between infants exposed to high versus low levels of homicide rates at the municipality level. Second, I use a DID model that analyzes the difference between being exposed to a homicide during pregnancy or not, relative to the analogous difference of being exposed within the 9 months following newborns' birth. I also examine whether the mothers' stress related to homicide exposure is attenuated when they were previously exposed to other crimes. Finally, I consider a maternal fixed effects model that considers mothers that had several children in the period examined and that were subject to different exposure levels. The results show that exposure to homicides during pregnancy generates a birth weight deficit of between 20 to 31 grams, compared to newborns exposed to homicides post-pregnancy. Moreover, the maternal fixed effects model shows that newborns exposed to homicides have a birth weight deficit of between 110 to 257 grams, compared to their non-exposed siblings. Additionally, exposure to homicides generate gestational length reductions, and a decrease in the 1st minute Apgar score.

The results highlight the importance of establishing social and health policies targeted to address the stress and insecurity of the affected individuals. Government's efforts should aim to offer prenatal controls and psychotherapies to safeguard the mental health of mothers exposed to violence during pregnancy. Moreover, policy interventions should include all the women and newborns living under violence stress and not just the direct victims of violence. Future research should examine the long-term consequences of prenatal exposure to homicides on child health and cognitive outcomes, as well as on maternal welfare.

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