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Office of Strategic Planning and Development Effectiveness

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TECHNICAL NOTE Nº IDB-TN-01731

January 2019

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IDB
Inter-American Development Bank

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Aparicio, Gabriela.
Gender gaps in birthweight: the effects of air pollution across Latin America / Gabriela Aparicio, María Paula Gerardino, Marcos Rangel.
p. cm. — (IDB Technical Note ; 1731)
Includes bibliographic references.
1. Birth weight-Effect of air pollution on-Latin America. 2. Birth weight-Sex differences-Latin America. 3. Air-Pollution-Health aspects-Latin America. I. Gerardino, María Paula. II. Rangel, Marcos. III. Inter-American Development Bank. Office of Strategic Planning and Development Effectiveness. IV. Title. V. Series.
IDB-TN-1731

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1300 New York Ave NW, Washington DC 20577

Gender Gaps in Birthweight:
The Effects of air pollution across Latin America[1]

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Abstract

Recent estimates indicate that more than 100 million people in Latin America and the Caribbean are exposed to air pollution levels exceeding World Health Organization guidelines. Air pollution remains due to the process of development centered in high rates of urbanization (and congestion), geographically concentrated industrialization, and biomass burning. However, there is limited systematic evidence across the region on the impact of in-utero exposure to air pollution over infant health and well-being. Health at birth is known to have long term consequences, so this investigation seems warranted. A particular feature of pregnancies is that male fetuses are more delicate than females and are, therefore, expected to be more strongly affected. This paper looks at the effects of fetal pollution-exposure on birthweight and examines whether air pollution concomitant to economic development is indeed more harmful to male than female fetuses. We find that that a 10% increase in pollution exposure in-utero reduces the gender birth-weight gap by approximately 50 grams, equivalent to smoking 5 cigarettes a day while pregnant. Family fixed effects specification are employed to control for unobserved confounding factors such as family background. Several countries in the region are studied relying on comparable health survey data and satellite-based pollution data.

JEL Codes: Q53, J16, J13

Keywords: air pollution, health, education, satellite data, particulate matter, birth-weight.

[1] The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Inter-American Development Bank, its Board of Directors, or the countries they represent.

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1. Introduction

Recent estimates indicate that more than 100 million people in Latin America and the Caribbean are exposed to air pollution levels exceeding World Health Organization guidelines (Cifuentes et al., 2005). Though important efforts[5] have been made during the last two decades to improve air quality in the region, air pollution remains high in many of the region's main urban centers and is becoming an issue in emerging cities. Outdoor air pollution tends to be worse in lower-income urban communities, affecting precisely those families that have the least resources to protect themselves. Urban air pollution is primarily the result of burning fossil fuels and the key sources are transportation, electricity generation, and industry. Pollution is also high in certain rural areas of the region, mainly due to deforestation and biomass burnings (Provençal et al., 2017).

Several epidemiology studies have linked particulate matter and aerosols to adverse health outcomes early in life. For example, in-utero exposure to pollution has been linked to infant mortality, pre-term delivery, as well as low-birth weight, amongst other. As a result, it is now considered as important for pregnant women to avoid air pollution as it is to avoid smoking (for a discussion, see UNICEF (2016)). Although, there is limited evidence of the differential effects of air pollution by gender, recent evidence seems to suggest that male infants may be more adversely affected by pollution. For example, in Canada, historically male newborns have been on average modestly heavier than females; however, over the past two decades, the difference in size between the sexes has been diminishing. The shrinkage in this gap has declined by about half of one per cent per year. Researchers suggest that chemical pollutants that interfere with hormones and that affect males during fetal development more severely than females may be to blame (Van Vliet et al., 2009). Evidence shows that harmful chemicals, with antiandrogenic properties affecting the endocrine system of infant males, can attach to aerosols and particulate matter. Interestingly, a similar phenomenon appears to be at work in Latin America. Relying on administrative data for Colombia, Figure 1 shows that the shrinkage in the birth-weight gap between males and females is also noticeable for this country and is comparable in magnitude to that in Canada.

This paper looks at the effects of fetal exposure to air pollution on infant weight outcomes across several Latin American countries. Furthermore, we study the heterogeneous effects of pollution exposures on boys versus girls. The time spent in-utero is a critical period of children's development. Exposure to elevated levels of pollution while in-utero can have harmful and long-lasting effects. . We extend the analysis to examine variation in pollution exposure across siblings, allowing to control for confounding factors such as family decisions regarding pollution avoidance. Moreover, if boys and girls have critical stages of development at different months of the

[5] For example, several cities have implemented integrated air quality management plans and have made sectoral investments, such as sustainable urban transport.

pregnancy and they are affected differently by external factors, the month and level of pollution exposure may lead to different outcomes for boys versus girls. Hence, differential effects by gender may be driven by children's sex link physiological differences in the timing of development in-utero or hormonal differences rather than social factors or maternal behavior.[6] Our results suggest, that there is a negative effect of higher pollution exposure in-utero on birth-weights, particularly for male babies. The main finding of the paper is that a 10% increase in pollution exposure in-utero appears to reduce the gender birth-weight gap by approximately 50 grams. The economic magnitude of these effects is significant and very harmful. A 10% increase in pollution has as similar impact on the gender birth-weigh gap as smoking 5 cigarretes a day.

We take advantage of comparable data across countries. Health outcomes are obtained from multiple rounds of the Demographic Health Surveys (DHS) for Bolivia (2008); Peru (2012), and Colombia (2010 and 2015).[7] Our main outcomes of interest are birth-weight in grams, and an indicator for low birth-weight. In particular we combine these data with pollution data in the form of aerosol index (AOD) obtained from NASA's MODIS database. The aerosol index is a qualitative measure of aerosols and a good predictor of particulate matter. The data was aggregated at the monthly level and was assigned to each child based on the months of exposure in-utero conditional on their date of birth and the municipality of residence of the mother during the baby's gestation period.

Though epidemiology studies have contributed greatly to understand the effects of pollution on health outcomes, and the physiological channels driving those effects; epidemiology studies tend to focus on correlations rather than causality. Failing to control for household characteristics and variation in economic activity may result in biased estimates of the causal effects of pollution on infant health. As a result, there is a growing literature in economics that aims to reliably estimate causal parameters. One of the biggest contributions of the economics literature to the topic is methodological: relying on more robust identification strategies, such as family fixed effects and instrumental variables, to account for potential confounding factors. However, the recent economics literature has two important limitations.

First, few economics papers study the effects of pollution exposure in-utero in the context of developing countries.[8] The impacts of pollution exposure in-utero in developing countries are

[6] We are not aware of any evidence that mothers may change their behavior, such as pollution avoidance choices, depending on the gender of their future child. Nonetheless, this type of behavioral responses can be plausible in some contexts.

[7] If data permits, additional outcomes will also be considered, such as current body mass index, health issues (i.e. asthma, allergies, cardiovascular disease) and mortality. school grade for age, and other educational outcomes.

[8] Even in the epidemiology literature, evidence for developing countries, and Latin America in particular, is limited. A recent meta-analysis of 1628 studies in the region found that most of the evidence is concentrated in a few cities and that some presented high risk of bias (Fajersztajn et al., 2017).

of independent interest. It has been hypothesized that the effects of pollution may be larger in developing countries than in developed countries. This may occur, for instance, because pollution levels are generally higher and infant health is often worse in developing countries (Currie et al., 2014). Arceo et. al. (2015) is one of the few economics papers studying the effects of pollution exposure in-utero in the context in a developing country, and comparing their findings to those of more advanced economies.[9] Interestingly, their estimates of the effects of PM10 on infant mortality for Mexico tend to be similar (or even smaller) than estimates for the US. However, is not clear whether these findings can be extrapolated to other countries in Latin America.

Second, to the best of our knowledge, there is no paper in the economics literature studying, systematically, the differential effects of in-utero pollution exposure by gender. The few available pollution studies with a gender focus in the economics literature, have generally looked at outcomes later in life, such as education and labor market outcomes. As is the case with the epidemiology literature, these studies tend to find that adult women may be more adversely affected by pollution than men. Higher vulnerability of women appears to be driven, at least to some extent, by social factors. For example, cognitive damage caused by pollution exposure may affect the subsequent human-capital investment decisions for women more than for men (Molina, 2016). However, it is not clear whether these findings can be extrapolated to other age cohorts. A more thorough understanding of the effects of air pollution is important to implement policies that effectively address its harmful effects.

The paper's main contribution to the literature is showing that pollution exposure in-utero reduces birth-weight notably more for infant males than for females, even when relying on a more rigorous identification strategy than those commonly used in the epidemiology literature. Our preferred specification controls for family fixed-effects, ensuring that results are not affected by family characteristics that remain constant over time, such as socioeconomic status, and pollution abatement preferences. This main result remains qualitatively unchanged across several specifications and robustness checks. Thus, the paper provides supportive evidence, that the male vs. female birth-weight gap may be shrinking due to augmented air pollution across the region. However, when considering the aggregate effects of pollution on birth-weight (that is, combining the effects for both boys and girls) our results are somewhat inconclusive.[10] The fact

[9] The evidence in the economics literature for Latin America is even scarcer. We are aware of only a few papers studying pollution exposure in-utero for Mexico (Arceo et al., 2015), Chile (Miller and Ruiz-Tagle, 2018), and Uruguay (Balsa et al., 2014). There are also few economic studies for Latin America, focusing on the effects of pollution later in life (see for instance, Miller and Vela, 2013).

[10] Our results are not always robust across different specifications. Though there is some indication that pollution reduces birth-weight, additional research is needed to confirm this finding. For the specifications where the effects of pollution on birthweight is negative and statistically significant at conventional levels, the magnitude of the effects is not any larger than for studies focusing on the US.

that the more aggregate models ignore important heterogeneity highlights the importance of considering the gender perspective when studying the effects of pollution exposure in-utero.

2. Literature Review

The epidemiology literature has long discussed the harmful effects of pollution exposure in-utero on human health. Epidemiology studies have linked particulate matter and aerosols to adverse health outcomes, such as cardiovascular disease, and even cancer. However, it is only recently, that pollution has become a relevant topic in the economics literature. Two important contributions of the economics literature to the field are: (a) the focus on causal estimates rather than correlations, and (b) the study of different measures of well-being in addition to the more traditional health outcomes. Currie et. al. (2014) provide a very complete discussion of the literature up to 2014. Hence, in this section, we briefly summarize their main findings and complement it with more recent studies. Special emphasis is given to studies that focus on gender.

2.1 Epidemiology Literature

Several epidemiology studies have linked particulate matter and aerosols to adverse health outcomes at all stages of life. Elevated levels of fine particulate matter are associated with increased mortality due to cardiopulmonary diseases, acute respiratory infections and cancers. Importantly, the harmful effects of air pollutants have been shown to begin in-utero, when cells are particularly sensitive to the damage caused by environmental toxins. Ultrafine air pollutants can cross the placental barrier, injuring the developing fetus when the mother is exposed to pollutants. In-utero exposure to pollution has been linked to various disorders for the infant, such as mortality, pre-term delivery, as well as low-birth weight, amongst other. As a result, it is now considered as important for pregnant women to avoid air pollution as it is to avoid smoking (for a discussion, see UNICEF (2016)).

Epidemiology studies have also highlighted gender disparities on vulnerability to air pollution. Though the literature is far from conclusive, most evidence amongst adults and older children suggests that females are more severely affected by pollution than males. However, evidence shows that the opposite is true amongst younger children –early in life, the adverse effects of pllution appear to be stronger amongst male fetuses and infant boys. Higher polllution sensitivity for males early in life is far from surprising, as epidemiology studies suggest that male fetuses are more delicate than females (Drevenstedt et al., 2008). Male fetuses may be more at risk due to diverse phisiological reasons such as sex-differing lung function growth rates, and lower respiratory volumes due to greater airway resistance, amongst other (for a discussion, see Clougherty (2011)).

2.2 Economics Literature

Infant Health and Children's Wellbeing

Both in the epidemiology and the economic literatures, most papers on the effects of exposure to air-pollution in-utero have focused on very short-term outcomes (such as the effects on infant health) or medium-term effects (such as the well-being of small children). Evidence from developed countries shows that exposure to higher pollution in-utero result in: (a) higher infant mortality, reduced birth weight and reduced gestation length; and (b) higher hospitalizations for respiratory infections or asthma for small children (see studies cited in Currie et. al. (2014)).

Particularly relevant for this study is Currie et al. (2009), which uses a similar identification strategy as the one exploited in this paper. They study a large sample of infants born in New Jersey from 1989 to 2006 and who were subjected to various levels of pollution in utero. By including family fixed-effects, they control for the fixed effects of family background shared by siblings. Their estimates imply that, on average, moving from a high-CO area to a low-CO area would have a larger effect on infant health than having a pregnant woman reduce her smoking from ten cigarettes a day to zero. Also relevant for this study is Sanders & Stoecker (2015), which is one of the few to consider differential effects by gender. They examine the effects of pollution on sex ratios at birth. Consistent with the hypothesis that male fetuses are more fragile than female fetuses, they find that a reduction in pollution increases the fraction of male fetuses. Lower male rations are interpreted as an indication of fetal losses.

Studying the effects of pollution in developing countries is important as effects may not be the same as in developed countries. Given that developing countries have lower levels of health, it is plausible that similar levels of pollutions may have much larger health impacts in less developed countries (i.e. effects may be non-linear). The availability of studies focusing on developing countries was initially quite limited due to data limitations (i.e. pollution and health data are not available or may not be reliably recorded). Though the number of studies for developing countries remains limited, recent papers have begun to overcome the data difficulties by relying on satellite data, as done in this paper.

Jayachandran (2009) use satellite aerosol measures to track smoke from fires in Indonesia in 1997. Results show a reduction in cohort size for those cohorts exposed to the fires' smoke during the third trimester of pregnancy. This suggests that fires resulted in a 20% increase in deaths among fetuses and children less than 3 years of age. Foster et al. (2009) also use satellite measurements to approximate pollution levels throughout Mexico. Using participation in a voluntary pollution reduction program as an instrumental variable, Foster et al. show that reductions in pollution improve infant mortality from respiratory causes. Also focused on Mexico, Arceo et. al. (2015) use thermal inversions, which trap pollution, as an instrumental variable and find that CO has stronger per-unit effects on infant mortality than in the United States. To the best

of our knowledge, there are no studies focusing on differential effects by gender of in-utero pollution exposure in developing countries.

Long-term Outcomes

Though the number of studies focusing of pollution exposure in-utero on long term outcomes has been growing, the available number of studies remains small. The main limitation is the difficulty finding datasets that allow linking in-utero environmental quality with adult outcomes. To overcome these difficulties many of the available studies have focused on cohort studies, comparing cohorts' exposure to some major pollution event to cohorts born just before. Almond et al. (2009) and Black et al. (2013) study nuclear disasters in the Ukraine and Norway, respectively. Nilsson (2009) investigates the long-term impact of banning leaded gasoline in Sweden during the 1970s. Sanders (2012) studies reductions in US pollution caused by the recession of the early 1980s. Isen et al. (2017) exploit the US Clean Air Act of the 1970s and use restricted-access data on adult earnings by county and date of birth.

Few studies on long term-outcomes are available for developing countries. Using a large data set that follows Chilean children from birth, Bharadwaj et al. (2017) examine the relationship between air pollution exposure in each month of pregnancy and fourth- and eighth-grade test scores. They find significant effects of exposure to CO (and its correlates) and ozone in the third and fourth months of pregnancy, a timing that is consistent with the results found in Black et al. (2013) and Almond et al. (2009).

3. Data

Data comes from different sources including: satellite-based pollution data, and Demographic Health Surveys (DHS). These datasets are described below:

Satellite-based Pollution Data:

Though diverse types of air pollutants exist, particulate matter and associated aerosols are amongst the most widespread and among the most dangerous. Particulate matter and aerosols are solid or liquid particles suspended in the air. These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. While primary particles are emitted directly from a source (i.e. road dust, smoke from fires, etc.), secondary particles form in complicated reactions in the atmosphere between primary particles and other chemicals (i.e. chemicals emitted from power plants, automobiles, etc.). In addition, particulate matter and aereosols contain a large proportion of Black Carbon (BC), which has emerged over the last few years as a major contributor to global climate change. Particulate matter is one of the most widely

studied types of air pollution, in part due to data availability from ground-stations in developed countries and from satellite sources.

Data on air quality was obtained from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Aerosol Optical Depth (AOD) products, which have been recently used in the economics literature to study the health effects of air pollution and other topics (Foster et al., 2009; Gendron-Carrier et al., 2018; Hansen-Lewis, 2018). MODIS daily data is available for the globe since 2000.[11] AOD is a well-established proxy for surface air quality, and it has been shown to be highly correlated with measures of suspended particulate matter (such as PM10 and PM2.5). The main benefit of AOD relative to ground-based air quality measures is that it is available at high temporal frequency (daily in our case) and on a global scale, allowing to have consistent measurements across different regions (urban vs. rural) and countries. This is particularly important for this paper as different countries are studied. In addition, MODIS has high spectral resolution which enables it to detect clouds and aerosols better than previous satellite-based instruments.

There are, however, some drawbacks of AOD relative to ground-based air quality monitor data.[12] Unlike ground-based stations that monitor particulate matter on the surface, AOD measures are taken higher in the atmosphere and may not accurately reflect the situation on the surface. It is the condition on the surface that matters the most for health effects. In addition, satellite observations only make coarse characterizations of the aerosol type, such as dust, sulfate, smoke, or mixed. The type and chemical composition of particulate matter, and not only the concentration of particles, is likely to affect health outcomes. Despite these limitations, AOD is expected to effectively capture large variations in air quality, which is the primary interest in this paper.

MODIS aerosol data products come at different levels of processing. Level 1 (L1) data is generally raw; level 2 (L2) data includes minimal processing; whereas level 3 (L3) includes higher level of processing by NASA (i.e. data is provided at equal grids). Generally, higher processing levels allow for easier manipulation at the cost of less flexibility. While recent papers have used L2 data, we have opted for using L3 data as the variability of interest is at the municipality level and very fine geographic measurements are not needed (municipalities are the smaller geographic units that can be matched with health data in the DHS). The specific AOD dataset used in this paper is the MOD09CMA product, which has a spatial resolution of 0.05 degrees (approximately 5 km per pixel) and includes only AOD measures over land (Terra satellite).[13] The

[11] Other satellite measures of aerosol are also available and may be used as robustness checks. TOMS data is available sin ce the 70s. OMI data is more accurate than TOMS but it is only available since 2005.

[12] Also, some ground-stations have the advantage of monitoring additional pollutants (i.e. ozone, sulfur and nitrogen oxides); but this is often not the case in many developing countries.

[13] The name of the aerosol data used is "MODIS/Terra Aerosol Optical Thickness Daily L3 Global 0.05Deg CMA" (MOD09CMA). Other MODIS products also include aerosol measures over water based on MODIS Aqua satellite.

data has been processed by NASA to account for clouds and high solar zenith angles; and is generally used for climate modeling.[14]

MODIS products report AOD on a scale from 0 to 5000, which is generally normalized to take values between 0 and 5.[15] Rescaled AOD values can be interpreted as being in a log scale from 0 to 5. AOD below 0.1 is considered clear and the maximum possible of 5 means that sunlight cannot pass through the air. Since AOD is already on a log scale, additional log transformation of the data is unnecessary (Hansen-Lewis, 2018).

Research in atmospheric science has validated MODIS AOD as a measure of ground-level fine particulate matter globally as well as in several countries (for a recent discussion see Gendron-Carrier et. al. (2018)).[16] This literature concludes that AOD is a good measure of airborne particulates, with two caveats. First, there are some conceptual differences between satellite-based AOD and ground-based measures of particualte matter. Satellite-based AOD measures daytime average conditions over a wide area at the specific time the satellite passes overhead, while ground based instruments record conditions at a specific location, often over a period of hours. Second, ground based instruments report the concentration of dry particulates, while satellite-based measures cannot distinguish water vapor from other particles. Hence, some divergence between satellite and ground based measures is to be expected, and it is importat to controll for variations in climate when relying on AOD measures, to account for humidity.

Pollution Patterns in Latin America:

We provide a simple validation of the AOD data used in this paper as a pollution proxy for three selected cities. Figure 2 compares satellite-based AOD with measures of pollution from ground-based readings from the World Health Organization database (WHO, 2016). Particulate matter can be of different sizes, but the most common particle sizes are PM_{10} and the finer $PM_{2.5}$. The WHO database collects information on on average annual PM_{10} and $PM_{2.5}$ concentrations (mg/m3) for cities around the world, where ground-stations are available. Figure 2 suggests that broad characterizations of pollution levels across cities, based on AOD and PM_{10}, are qualitatively comparable. Considering either AOD or PM_{10}, Lima is by far the most polluted city, followed by Bogota and then La Paz. Importantly, all three cities have PM_{10} levels above the maximum annual average exposure level of 20 mg/m3 recommended by the WHO, and AOD levels exceeding the 0.1 threshold of clean air suggested in Hansen-Lewis (2018).

[14] https://modaps.modaps.eosdis.nasa.gov/services/about/products/c6-nrt/MOD09CMA.html

[15] The MOD09CMA data can take values slightly higher than 5000 because of the processing.

[16] To further validate the validity of the AOD measures used here, later versions of the paper may include correlations between AOD and the level of suspended particulate matter (PM) from available air pollution monitors, such as the ones in Colombia (which have publicly available data).

The above findings are not surprising. As discussed above, an extensive literature finds that AOD presents similar patterns to PM_{10} and $PM_{2.5}$ measures despite the conceptual differences between the two. A more detailed validation of AOD, also relying on WHO data, is presented in Gendron-Carrier et. al. (2018). Basen on several linear models, they show that AOD tracks particulate matter measures relatively closely even in a simple model without additional controls. In general, they obtain R-squares of over 0.75. Though their analysis can provide a basis for translating the AOD measure into PM_{10}, it does not fit our data closely, probably because we use different versions of MODIS AOD data (the L3 data used here has been procesed further for use in climate modeling). Instead, we rely on a coarser rule of thumb to translate AOD to PM_{10} measures. In Figure 2, the left axis shows the raw AOD mesure, whereas the right axis shows the OAD transformation to PM_{10}. The two axis in this figure can be used to coarsely translate between both pollution measures. For reference, the horizontal line in the figure gives the WHO recommended maximum annual average PM_{10} exposure level of 20 mg/m3.

Figure 3 describes broad trends in mean AOD over time for selected countries and cities in Latin America between 2000 and 2015. We notice that AOD has remained quite flat over time whether we look at countries or cities. This is consistent with evidence presented elsewhere. Most studies of pollution in Latin America, suggest that for the entire region, as well as for most individual cities, pollution has remained flat, or is decreasing slightly (Provençal et al., 2017). However, the current situation in Latin America is still worrisome as pollution has remained flat at relatively high levels. On average, Colombia, Peru, and Bolivia have AOD levels that are considered polluted, as they are above the 0.1 threshold.

A thorough discussion of pollution trends over time is particularly important in our context, as our identification strategy (discussed in the next section) relies on the variation of pollution within a given municipality/district over time. Though Figure 3 seems to suggest that there is little time variation in pollution levels over time, it is important to consider that this figure presents annual averages, and consequently it may be hiding much variation in pollution that occurs within a given year. Figure 4 shows a histogram of over 500,000 municipality-month pollution observations available for Peru, Colombia, and Bolivia over 2000-2015.[17] We notice that municipality-month pollution levels take a number of different values, ranging from 0 to 0.4, with most of the distribution concentrated above the 0.1 threshold for clean air. This wide range in values suggest that there may be important variability in pollution.

Further evidence of the variation of pollution over time, within each location, is presented in Figure 5. The figure shows box-plots of the distribution of monthly pollution levels for Bolivia, Peru and Colombia. To construct the figure, we first calculated monthly pollution averages in each

[17] No all of this variation will be used in the paper as the DHS data is not avaliable for all municipalities/districts and all time periods.

country, so that the box-plot captures only time-variation in pollution and not geographic variation. The box-plots show that there is important variability over time in pollution, even within a specific location, and even though long-term pollution trends are quite stable. When looking at specific cities, the variability in pollution over time is somewhat smaller, but remains important for some cities such as Lima. There are many reasons for pollution levels to vary within a year in a given location. For example, the months that schools are in recess there may be less congestion, and consequently lower pollution levels. Similarly, industries that emit pollution may be more active in certain months than other. Climatic factors may also play a role. Winds that move pollution into or out of a given location, may vary in strength across different months. Similarly, the likelihood of inversion episodes that trap pollution in a given location also varies over time.

Demographic Health Survey (DHS) Data:

Infant health outcomes were obtained from several rounds of Demographic Health Surveys (DHS), which provide comparable data for several countries. Specifically, this paper focuses on DHS data for Bolivia (2008); Peru (2012), and Colombia (2005 and 2010). The main outcomes of interest are birth-weight measures.[18] Other relevant information is also collected in the survey such as gender, household characteristics, etc.

Descriptive statistics are shown in Table 1. Panel A focuses on our main outcome of interest. It shows the distribution of the birth-weight of children by country and gender. On average, boys weight around 100 grams more than girls in all the countries. On average, children are heavier in Bolivia and lighter in Peru. The mean birth weight for girls varies between 3,271 and 3,155 grams, and for boys between 3,393 and 3,265 grams. Panel B displays additional summary statistics of the children characteristic by country. In terms of low birth weight, less than 10 percent of children were born with this condition in the three countries. However, the standard deviation of this measure is large and varies between 23 and 27 percent. In the sample, children characteristics across countries are very similar. On average, the children are around 2 years of age, 51 percent are boys, and almost every child is alive.

Matched DHS-pollution Data:

The DHS survey includes geographic information that can be used to merge the health and demographic data with the other sources of information, such as the AOD pollution proxy discussed earlier. We rely on the official municipality codes for Bolivia and Colombia and district codes for Peru to merge the data. Both municipalities and districts are equivalent 3rd level administrative units. First, pollution data was aggregated at the monthly level by choosing the median value occurring in a given month for each 5 km pixel. Then, municipality-month pollution

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[18] If data permits, additional outcomes will also be considered.

levels were obtained by calculating the municipality average, for each given month, of all the monthly-level pixels that fall within the geographic boundaries of a given municipality/district. Nine municipality-month pollution measures were assigned to each child in the birth records of the DHS survey conditional on their date of birth and the place of residence of the mother during pregnancy. Given that the duration of the pregnancy is endogenous, in all cases, it was assumed that the gestation period lasted for the full 9-month term. Finally, each child's average in-utero pollution exposure was obtained by averaging the municipality-month pollution levels for the 9 months corresponding to the expected gestation period.

Panel B of Table 1 also describes children's pollution exposition in utero specifically for children in the DHS survey. The average pollution exposition in-utero varies across countries ranging from 0.15 in Bolivia, 0.16 in Peru, and 0.19 in Colombia. Also, there is a lot of variation within countries. Even though on average Colombia seems to be the country where children are more expose to pollution, Peru has the municipality with the highest level of pollution exposure (0.79). It is important to consider that these are high levels of exposure relative to the recommend maximum pollution exposure in the literature.

Next, we study pollution patterns for the merged DHS-pollution dataset in further detail. The municipal averages of the in-utero pollution exposure of children in the DHS survey are presented in Figure 6, Figure 8, and Figure 10, for Bolivia, Colombia, and Peru, respectively.[19] The figures show that there is geographical variation in pollution and pollution is distributed as expected. For example, in Colombia pollution is concentrated in the more urban west, rather than the amazon at the east. In addition, the figures also show that pollution levels in the countries of interest are relatively high. The colors in the figures suggest that most municipalities exhibit pollution levels above the threshold defining clean air (pollution levels under 0.1 are considered clean air). The variation in pollution within municipalities is presented in Figure 7, Figure 9, and Figure 11 for Bolivia, Colombia, and Peru, respectively. Specifically, these maps show the interquartile range of in-utero pollution exposure of children in the DHS survey by municipality. We notice that there is some within municipality variation in in-utero pollution exposure.

4. Methodology

a. Baseline estimation

The baseline empirical strategy exploits the time-municipality variation in pollution. We test empirically the relationship between the average level of pollution in a municipality during the 9

[19] We followed the following steps to make the maps: first, we assigned to each child in the birth records of the DHS survey the pollution in the municipality where the mother resided during pregnancy, for the 9 months corresponding to the gestation period. After calculating each child's pollution exposure, we then calculated the average municipal exposure for children in the survey.

months of pregnancy of a women and different health outcomes. To account for wrongly assigned pollution exposure, we look at the effect of pollution on children that their families have lived in the same location since before the child was conceived.

For this purpose, we specify the following equation,

$$y_{i,m,t} = \beta_1 Average\ Pollution_{i,m,t} \quad + \beta_2 Male_i + \mu_b + \tau_m + \varepsilon_{i,m.t} \qquad (1)$$

where y is the health outcome variable for child i, in municipality m, in year-month t of birth. The term $Average\ Pollution$denotes the average pollution to which a child is exposed while being in-utero during the 9 months prior to delivery. $Male_i$ is equal to 1 if the child is a boy and 0 otherwise. μ_b corresponds to month of birth fixed effect that accounts for seasonality differences and τ_m represents municipality fixed effects that control for all time invariant characteristics varying at the municipality level. $\varepsilon_{i,m.t}$ is the error term.

To identify children's exposure to pollution while in-utero, we consider boys and girls in the DHS birth roster (those born up to 5 years before the time of the survey) and we match their municipality of residence at the time of conception with the data on pollution by municipality. We compare the health outcome of children within municipalities that are affected with different levels of pollution. Because, we control for municipality fixed effects, the coefficient that captures the effect of pollution is identified using changes within municipalities over time. As a result, estimates will measure the average effect of pollution with reference to municipality averages.

One potential concern with the estimation proposed in equation 1 is that family characteristics may have an effect on how they respond to pollution and take care about the health of the mother and the children. As a result, we also estimate additional specifications that control for household fixed effects instead of municipality fixed effects (equation 2), where τ_f are household fixed effects.

$$y_{i,f,t} = \beta_1 Average\ Pollution_{i,f,t} \quad + \beta_2 Male_{i,f} + \mu_b + \tau_f + \varepsilon_{i,m.t} \qquad (2)$$

Controlling for household fixed effects is crucial given that children from more disadvantaged households tend to have lower health and educational outcomes. In addition, household fixed effects may also help to control for some of the determinants for the decision to move to different locations (locational sorting). Given that household characteristics may be correlated with the decision to migrate, controlling from household characteristics may help to address some of the biases arising from households that choose to relocate. The effects of

interest will be identified by the variation in pollution across time, which results in siblings being exposed to different pollution levels. Thereby, differencing out any family-specific or municipality characteristics that affect children across families. This fixed effect model looks at the differences on health within families residing in municipalities with different levels of pollution and that have more than one child.

To consistently estimate the causal effect of pollution on birth outcomes, the main identifying assumption is that within families, changes in pollution are uncorrelated with unobserved changes in other factors that affect birth outcomes. There is a main threat to this identification. While controlling for household fixed effects may help to address several concerns; one may still worry that the level of pollution is endogenous. In particular, changes in the level of pollution over time may be correlated with economic activity.

b. Heterogeneous effects by gender

The difference between the number and health measures of boys and girls born has been interpreted as a natural selection response to differential survival prospects. We want to study if pollution also has an impact on these prospects.

To do this, we include the interaction term between the measure of pollution exposure and the gender of the child (equation 3).

$$y_{i,f,t} = \beta_1 Average\ Pollution_{i,f,t} + \beta_2 Male_{i,f} + \beta_3 Average\ Pollution_{i,f,t} * Male_{i,f} + \mu_b + \tau_f + \varepsilon_{i,m.t} \quad (3)$$

The main objective of this specification is to study if changes in pollution may have an impact on the gender differences in birth-weight; and therefore, if there is a differential effect of pollution conditional on gender. As a result, and according to equation (3), the main coefficient of interest is the interaction term between pollution variable and the male dummy (β3). This implies that the expected change in the gender gap in the health outcome due to an increase in pollution of δ will be given by (0.01 ∗ β3 ∗ δ) as pollution is measured in logs. Consequently, the expected change in the health measure for girls and boys would be equal to (0.01 ∗ β1 ∗ δ)) and (0.01 ∗ (β1 + β3) ∗ δ), respectively. This household fixed effect model looks at the differences on health outcomes within families residing in municipalities with different levels of pollution across time and that at a minimum have a boy and a girl in the household.

5. Main Results

The main results presented in the paper focus on the non-migrant sample. This sample includes only children for which the mother has been living in the same municipality since before the child was conceived. Though this is a selected sample, it reduces noise by ensuring that each child is assigned the level of pollution that corresponds to the municipality where the mother resided while expecting the child. In the Appendix, we present results for the full sample, including both migrant and non-migrant families as robustness checks. Results are qualitatively similar in both sets of tables. Hence, we discuss only the results for the non-migrant sample.

To study the effects of pollution on infant health, we rely on two main outcomes: (a) birth-weight (measured in grams), and (b) an indicator of whether the baby has low birth-weight. The birth-weight indicator is a common and very important outcome used in this literature.[20] The World Health Organization (WHO) has defined low birth-weight as the weight of live born infants of less than 2,500 grams, regardless of gestational age or any other etiology. Low birth weight (LBW) is one of the crucial factors affecting child morbidity and mortality worldwide; approximately one third of neonatal deaths are attributable to it.

The main result tables presented in the paper follow a similar structure. In each table, four models are presented, with each subsequent model controlling for additional confounding factors. In all cases we control for month of birth fixed effects because parents with different characteristics may choose to have children at different times; and because weather conditions that affect pollution may be different in different months. In addition, Model (1) controls for survey fixed effects to account for differences in DHS survey-rounds for different countries and survey-years. Model (2) controls for municipality fixed effects to account for differences across municipalities, such as variation in economic base, and labor market characteristics, etc. This model also controls for year of birth fixed effects to account for any overall trend in pollution. Model (3) controls for municipality-year of birth fixed effects to account not only for differences across municipalities, but also for the possibility of different trends over time in different municipalities. Finally, Model (4) controls for household fixed effects to account for differences in household characteristics, such as each family's preference for pollution abatement, as well as difference in socioeconomic status that affects food choices and availability. We cluster standard errors at the municipality-level, municipality-year level, or household-level for Models (2), (3) and (4), respectively.

Estimates of the association between pollution exposure-in utero and birthweight (measured in grams) are shown in Table *2*. Model (1) suggest that a 10% increase in pollution exposure in-utero is associated with a higher birth-weight of approximately 58 grams.[21] However,

[20] See for instance Currie et al. (2009).

[21] When interpreting the results in

given that differences across locations are not controlled for in these models, the results may be picking up locational differences. A positive association is to be expected because more prosperous municipalities tend to have higher economic activity, which results in higher pollution levels, but also in higher incomes to pay for better health and nutrition. The benefits associated with better health and nutrition may outweigh the negative of pollution, such that they are not perceptible in the regressions.

Model (2) improves upon the previous model by controlling for municipality fixed effects and year of birth fixed effects (the baseline model presented in Equation 1). Results suggest that a 10% increase in pollution exposure in-utero is associated with a lower birth-weight of approximately 27 grams. Hence, these results suggest that pollution may have a negative effect on infant health, as shown in the literature for developed countries. Model (3) controls for municipality-year of birth fixed effects. Though results are no longer statistically significant, the coefficient of pollution remains negative. However, estimates from Models (2) and (3) may be biased if different types of families choose to live in different locations. For instance, families that are more willing to spend resources in pollution abatement may live in cleaner cities; these families may also be more willing to spend in better health and nutrition.

Model (4) improves upon the previous models by controlling for mother fixed effects (the baseline model presented in Equation 2). Based on this specification the effects of pollution are not statistically significant at conventional levels. It is not entirely clear whether the lack of statistical significance occurs because pollution has no effects, or due to limitations of our data.[22] Table 3 is like Table *2*, but the dependent variable is an indicator for low birth-weight rather than weight in grams. Results are qualitatively similar to those obtained earlier. Hence the results presented thus far are somewhat inconclusive.

It is very important to consider, however, whether the results in Table *2* and Table 3 may be hiding potentially important heterogenous effects. In particular, we are concerned about the possibility of differential sensitivities to pollution by gender, suggested by the epidemiology literature. Relying exclusively on the results presented thus far, which fail to consider the gender perspective, and not exploring the effects of pollution any further may lead to incomplete conclusions and potentially flawed policy recommendations. Pollution exposure for pregnant women may still be a very important concern if it affects some types of babies, even if evidence

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, it is important to take into account that the satellite-based pollution measures used in the regressions should be interpreted as logarithms. Given that the model is linear-log, for a 1% change in pollution, the effect is calculated as the coefficient on pollution divided by 100. For a 10% change in pollution, the effect is calculated as the coefficient on pollution divided by 10.

[22] However, there is some evidence that this lack of statistical significance may be due to low statistical power. When controlling for mother fixed-effect, we consider only mothers with more than one child in the sample; this is a much more restricted sample than the one used in specifications that control for municipality fixed-effects instead. When restricting the sample used in all regressions only to families with more than one child, then the specifications controlling for municipality fixed-effects also lack statistical significance.

for the aggregate is inconclusive. Hence, in the remaining of the paper, we study the effects of pollution on the boy vs. girl birth-weight gap.

There are different reasons, our aggregate results may be inconclusive. One possibility is that pollution has a limited effect on birth-weights in developing countries, on average. Another possibility is that the lack of robustness of the results is driven by limited power due to the small number of observations available. While some of the research on this topic in developed countries relied on administrative data where many children are studied, this paper relies on survey data with a more limited number of observations. Survey data was used to ensure comparability across countries, and due to the limitations of administrative data in the region. For instance, in most cases it is not possible to identify siblings based on administrative data. In the case of Colombia birth-weight in grams is not available but only a categorical variable is recorded. If we are able to identify that pollution has more detrimental effects for one of the genders, in spite of the limitation of the survey data used in this paper, this would highlight the importance of focusing on the gender perspective when studying pollution.

Table 4 presents estimates of the heterogenous effects by gender of pollution exposure-in utero and birthweight. The main difference between Table *2* and Table 4 is that the later includes an interaction term between male births and pollution (as shown in Equation 3). As discussed in the literature review, male fetuses are more delicate than female fetus due to differences in physiological development. Hence, it is reasonable to expect pollution to have differential effects by gender.[23] In all models the interaction term between males and pollution has a negative sign (statistically significant at conventional levels), suggesting that pollution is more harmful for males. Most importantly, even when controlling for family fixed effects, higher pollution is associated with lower birthweights for males. A 10% increase in pollution is associated with a reduction in the birth-weight gap between males and females of between 30 and 50 grams, depending on the specification.

In order to put the magnitude of our results into perspective, we compare the effects of in-ture pollution exposure to the effects of smoking during pregnancy. Many epidemiology studies find very large reductions in birth-weight for mothers that smoke; however, as already pointed out, many of these estimates are likely to be contaminated by ommitted characteristics of the mother that are asociated with the smoking behavior. After controlling for mother fixed-effects, Currie et. al. (2009) finds that being a smoker reduces birth-weight by aproximately 39 grams and each additional cigarrete reduces it a further 2.2 g., for a total reduction of 50 g. in infants of women that smoke 5 cigarretes a day. Hence, a 10% increase in pollution, as measured by the AOD index, has as similar impact on the gender birth-weigh gap, as smoking 5 cigarretes a day has on

[23] In all models the male dummy is positive and significant, suggesting that males have a higher birthweight by approximately 150 to 200 grams.

the birth-weight of infant children. The economic magnitude of the effects presented is significant, suggesting that pollution exposure-in utero can be very harmful. Based on these results, the UNICEF (2016) recommendation that, it is as important for pregnant women to avoid pollution exoposure as it is to avoid smoking, seems warranted.

Table 5 is similar to Table 4 but the dependent variable of interest is low birth-weight, rather than weight in grams. Once again, results are qualitatively similar regardless of which of the two outcomes is used. Pollution seems to increase the probability low-birth-weight babies and reduce the birth-weight more for males than for females. Our preferred specification, which controls for mother fixed effects, suggests that a 10% increase in pollution increases the probability of low-birth weight by 2p.p. more for boys than for girls.[24] Controlling for mother fixed effects is important as families with better nutrition may also invest more in pollution abatement. In addition, there is evidence that gender difference in fetal growth are affected by maternal characteristics such as maternal height and weight (Lampl et al., 2009).

As discussed in the introduction, there is still limited understanding of the effects of pollution on the gender birth-weigh gap both in the economics and the epidemiology literature. However, the limited epidemiology literature available suggest that our results, that male fetuses are affected by pollution the most, are reasonable. There is evidence that the birth-weight gap between boys and girls is generated by androgen action, and some pollutant have anti-androgenic properties. Boys with androgen insensitive, syndrome have been found to have a comparable weight to girls (De Zegher et al., 1998); and anti-androgenic pollutants may be having a similar effect. Further, evidence shows that some critical time-windows of development may be slightly different in boys and girls, with boys developing earlier (De Zegher et al., 1999), and these differences in timing, may also play a role in our findings.

Table 6 studies whether higher pollution is associated with lower male births as suggested by some studies in developed countries. However, for this dependent variable no statistically significant effects can be found in any of the models presented.

6. Robustness Checks

In this section, we present several robustness checks for our main results, on the effects of pollution exposure in-utero on the gender birth-weight gap. The different robustness checks support the findings in Table 4 and Table 5, that pollution appears to be shrinking the gender birth-weight gap.

[24] When interpreting the results in Table 5 it is important to take into account that the satellite-based pollution measures used in the regressions should be interpreted as logarithms. Given that the model is linear-log, for a 1% change in pollution, the effect is calculated as the coefficient on pollution divided by 100. For a 10% change in pollution, the effect is calculated as the coefficient on pollution divided by 10.

6.1 Placebo Test

We conduct placebo tests to show that our main findings regarding the gender birth-weight gap are unlikely to be driven by different factors other than pollution. For this purpose, we replace the actual 9-month average in-utero pollution exposure with a random average exposure. This is done by reorganizing the actual municipality-month pollution levels in a random order. This ensures that the random pollution values are drawn from the same distribution as the real pollution values. Table 7 and Table 8 present the results for a single replication. We notice that after replacing actual pollution with a random pollution, the coefficients on the interaction between pollution and being a male are smaller in magnitude and no longer statistically significant at conventional levels. However, these results could be attributed to a lucky draw in the single replication presented. Hence, in Table 9 and Table 10 we present the results of a Monte Carlo simulation of 1000 replications of random pollution exposures on weight and low birth weight, respectively. Columns 1 to 3 correspond to simulations controlling for month of birth fixed effects and Municipality*Yearbirth fixed effects. Columns 4 to 6 shows results when including mother fixed effects. Columns 1 and 4, shows that the mean of the coefficients after 1000 simulations is close to zero for both outcomes and very small in magnitude relative to the effect estimated using the real exposure measure. Columns 3 and 6 shows the rejection rate calculated as the share of repetitions where the null hypothesis of effect is rejected at 5% level. This rejection rate is very low independently of the control variables use and the outcome variables.

Finally, we present the results of the placebo test graphically (see Figure 12) showing the distribution of the placebo coefficient estimates for the interaction between pollution exposures and being a male after 1000 replications. The vertical red line in the graph displays the estimated value of the interaction term based on the actual exposure. There is evidence of a large difference in magnitude of the simulation result and the actual coefficient.

6.2 Other robustness checks

The first set of additional robustness checks are presented in Table 11 and Table 12, for birth-weight in (grams) and an indicator for low birth-weight, respectively. These tables are similar to Table 4 and Table 5, but they also control for whether a child was the first-born. This is an important control, particularly for the specifications comparing the effects of pollution for siblings (Model (4)), as there is substantive evidence that the birth-weight of second-borns is significantly higher than that of first-borns. For instance, Bacci et. al. (2014) find that the birth-weight of first-borns is 89 grams lower than that of second-borns on average, but the magnitude of the effect

also varies by gender. To control for this potential confounding factor, we added to our base specification a dummy equal to unity if a child was the first child ever born to a given mother. As suggested by the literature, we find that the birth-weight of the first-born is, on average, between 60 and 80 grams lower than that of other children. However, including this additional control, does not change our main findings. As before, a 10% increase in pollution is associated with a reduction in the gender birth-weight gap of close to 50 grams for our preferred specification, which includes family fixed-effects; and the coefficients of interest are statistically significant at conventional levels for all specifications.

Our last robustness checks are presented in Table 13 and Table 14. The main difference between these tables and Table 4 and Table 5, is that we now focus on the full sample of births available in DHS data, rather than only those that households that did not migrate. Restricting the sample to only households that do not migrate is important to ensure that pollution is adequately assigned to each birth. However, this analysis has the disadvantage that relies on a selected sample. Households that choose to migrate may do so in part due to pollution. As before, results suggest that pollution is associated with a decrease in the gender birth-weight gap. However, coefficient estimates are not always statistically significant at conventional levels. Lack of statistical significance could be due in part to the noise introduced by imprecisely assigning the level of pollution to some children, or due to some endogenous household response to pollution that is not captured by our preferred estimates.

7. Conclusion

Recent estimates indicate that more than 100 million people in Latin America and the Caribbean are exposed to air pollution levels exceeding World Health Organization guidelines. However, there is limited rigorous evidence for the region about the impact of air pollution exposure while in-utero on infant health and well-being. Moreover, though epidemiological studies have found that male fetuses are more delicate than females, few papers in the economics literature have studied the differential effects of air pollution on birth-weight by gender. This paper shows that pollution has an effect on the shrinkage of the gender birth weight gap in disfavor of boys. Our results suggest that there may be an association between higher pollution exposure in-utero and lower birth-weights, particularly for male babies, who seem to be more delicate than females in-utero. The main finding of the paper is that a 10% increase in pollution exposure in-utero appears to reduce the gender birth-weight gap by approximately 50 grams, when pollution is measured by the AOD index. The economic magnitude of these effects is significant, suggesting that pollution exposure-in utero can be very harmful. A 10% increase in pollution (as measured by AOD), has as similar impact on the gender birth-weigh gap, as smoking 5 cigarretes a day has on the birth-

weight of children. Based on these results, the UNICEF (2016) recommendation that pregnant women should avoid pollution exposure as much as smoking, seems warranted.

Additionally, our paper suggests the importance to look at the hetergenous effects of pollution exposure by gender. We show that ignoring the gender perpective may be hiding important information and may lead to wrong policy implications. If the effects of in-utero pollution exposure on well-being are more important for a particular gender, then policy recommendations need to take this into account.

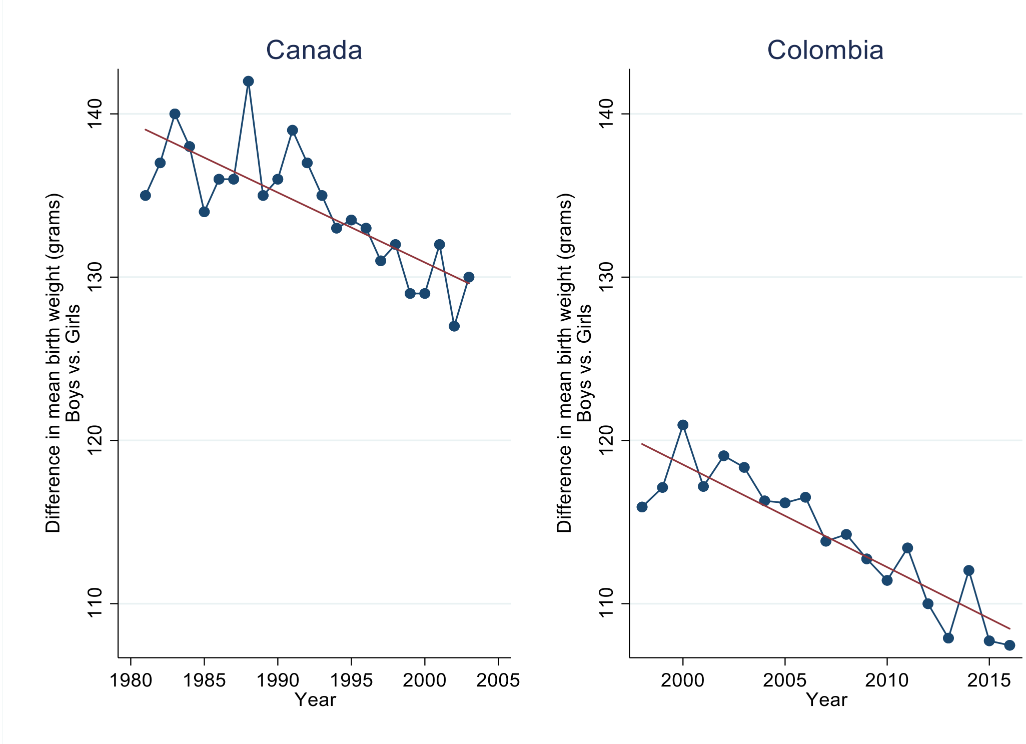
Though this and other recent papers have contributed to understand the effects of in-utero pollution exposure on well-being, the available research on the topic remains limited for developing countries, particularly those in latin America. Several opportunities for further reasearh are available. Future work could expand the evidence presented here by studying additional countries. An important advantage of relying on satellite-based pollution data and DHS surveys is that this data is comparable across countries, allowing to obtain a more detailed picture of the expected effects of pollution across Latin America. Moreover, additional outcomes should be considered such as whether babies are premature, as well as long-term outcomes like measures of education.

This paper uses as an identification strategy the comparison between siblings exposed to different levels of pollution in-utero, this improves upon the correlations comonly presented in the epidemiology literature, by controlling for mother/family characteristics that remain constant over time and that may have an effect on weight. However, one may still worry that the level of pollution is potentially endogenous. In particular, changes in the level of pollution over time may be correlated with changes in the family's economic activity and labor market outcomes. Future papers could exploit natural experiments or instrumental variables to address this concern. The use of thermal inversion as an instrument for polution seems quite promising. Temperature inversions are climatological phenomena that are independent of local pollution as well as local economic activity and trap pollution in a given location increasing its harmful effects.[25]

[25] Information on temperature inversion may be be obtained from NASA's AIRS database, as well as from ground-based stations.

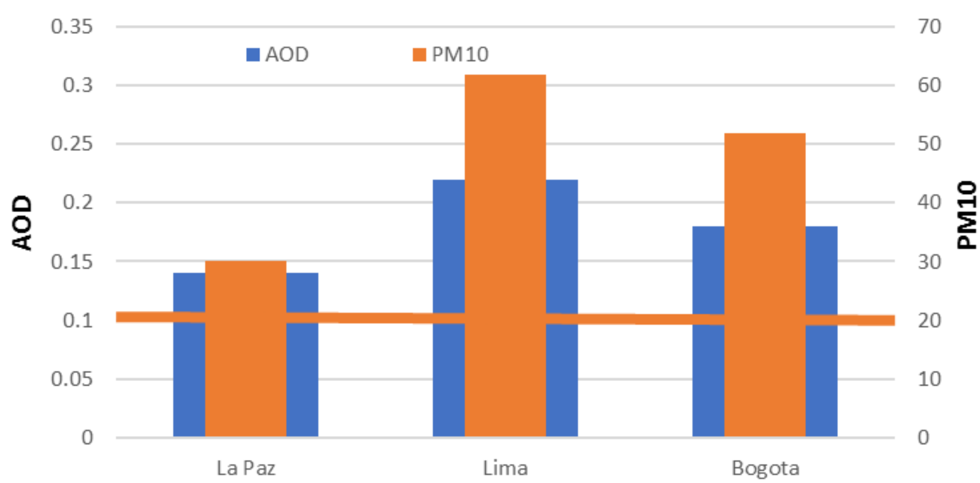
Figures

Figure 1: Difference in mean birth-weight by gender, Canada and Colombia



Source: Van Vliet et. al. (2009) for Canada. Own calculations based on administrative data for Colombia.

Figure 2: Comparison of AOD and PM10, Selected Cities



Note: The calculation of city-level AOD measures relies on the official geo-codes used in each country. La Paz city is identified based on municipality code 20101; Bogota is identified based on municipality code 11001; and Lima is identified based on district code 150101.

Figure 3: Pollution Trends, Selected Countries and Cities

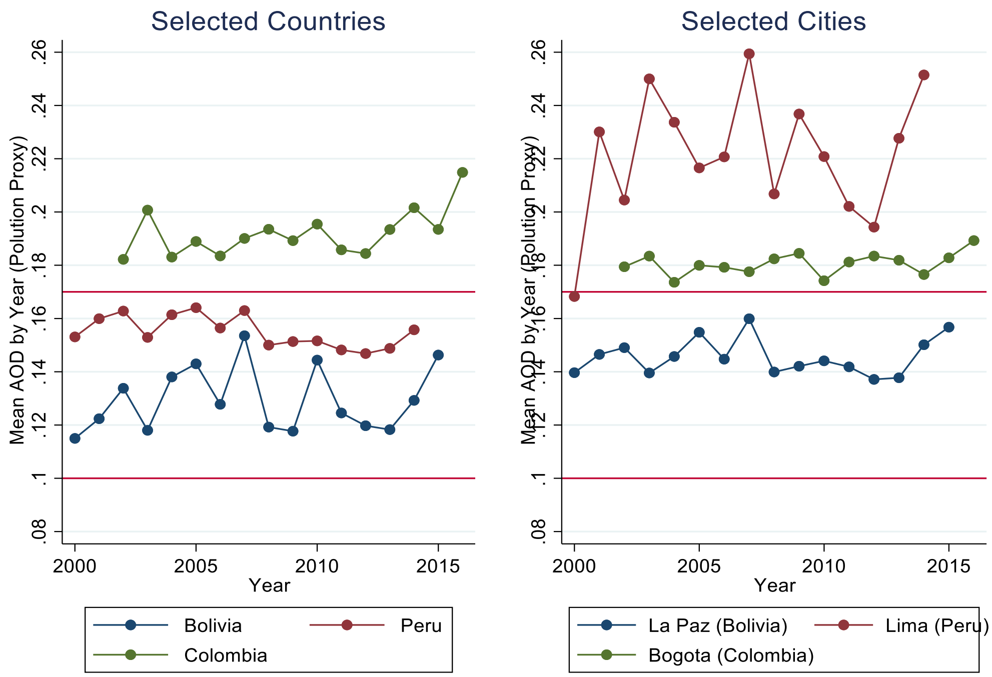


Figure 4: Histogram of Municipality-month Pollution Levels

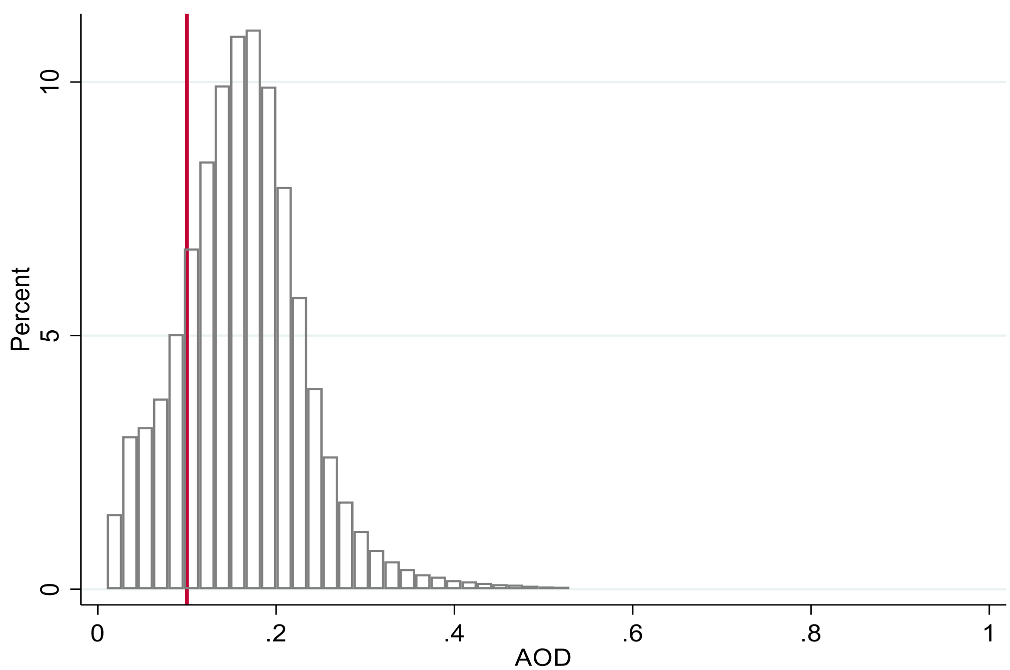


Figure 5: Box-plots of Pollution Variation within Selected Locations

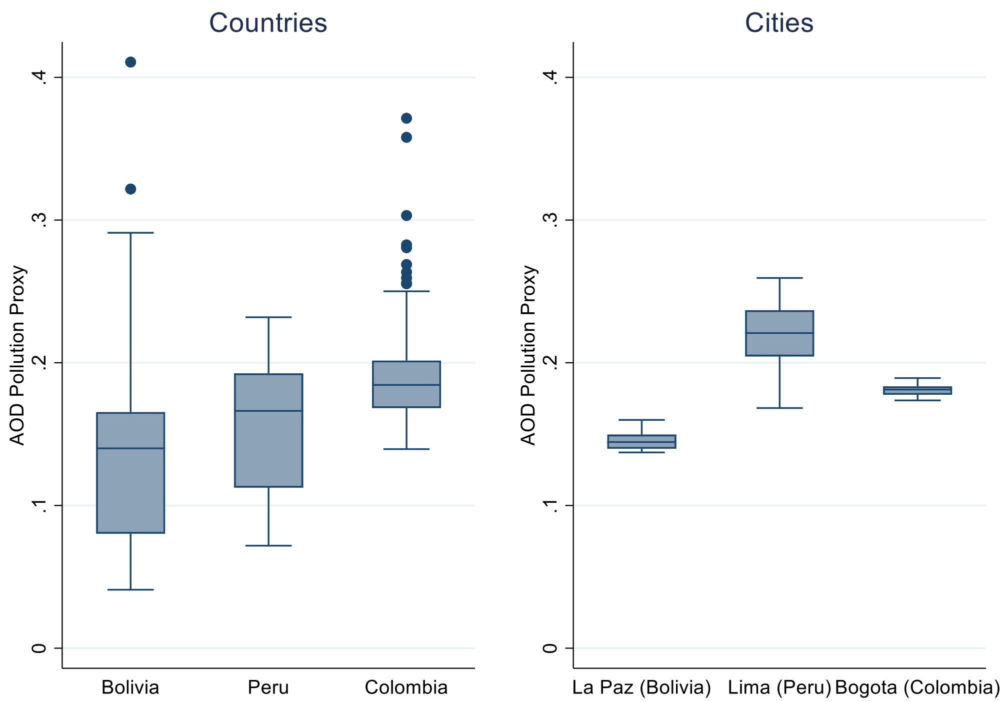


Figure 6: Municipal average of in-utero pollution exposure of children in DHS survey, Bolivia

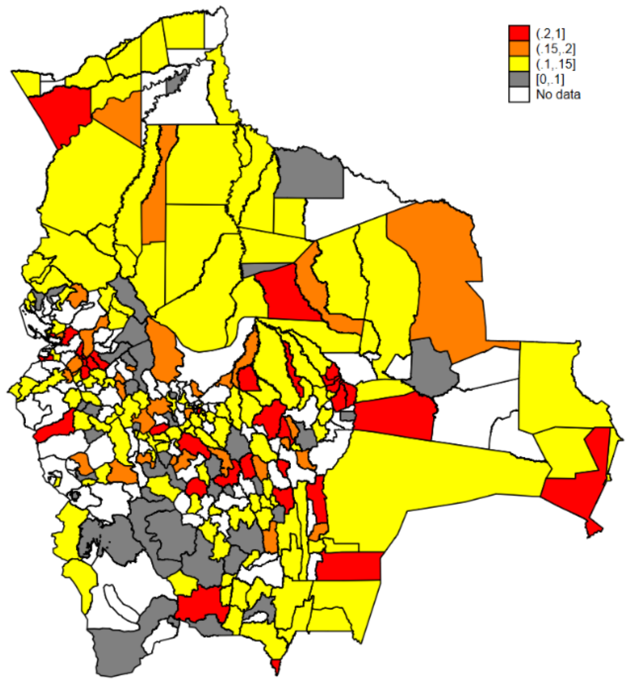


Figure 7: Municipal inter-quantile range of in-utero pollution exposure of children in DHS survey, Bolivia

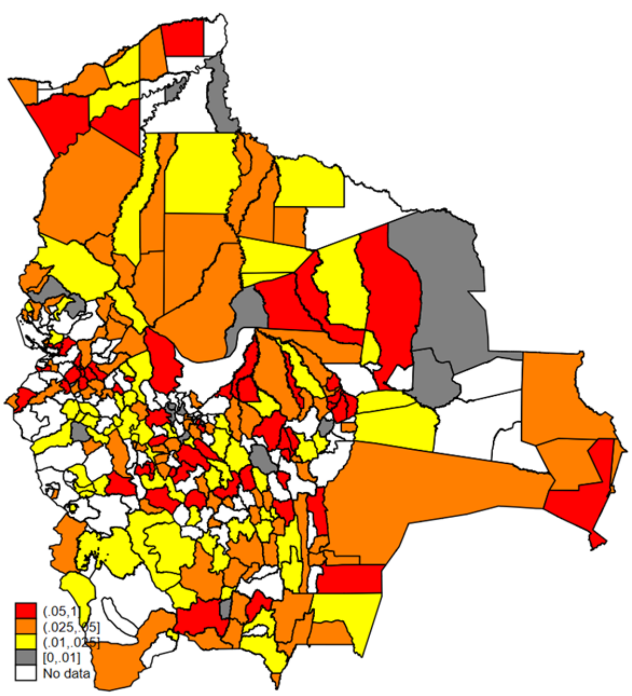


Figure 8: Municipal average of in-utero pollution exposure of children in DHS survey, Colombia

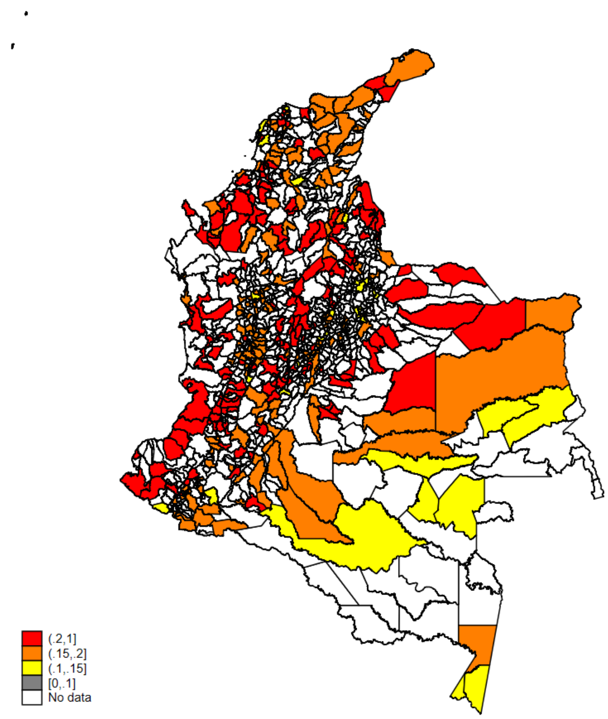


Figure 9: Municipal inter-quantile range of in-utero pollution exposure of children in DHS survey, Colombia

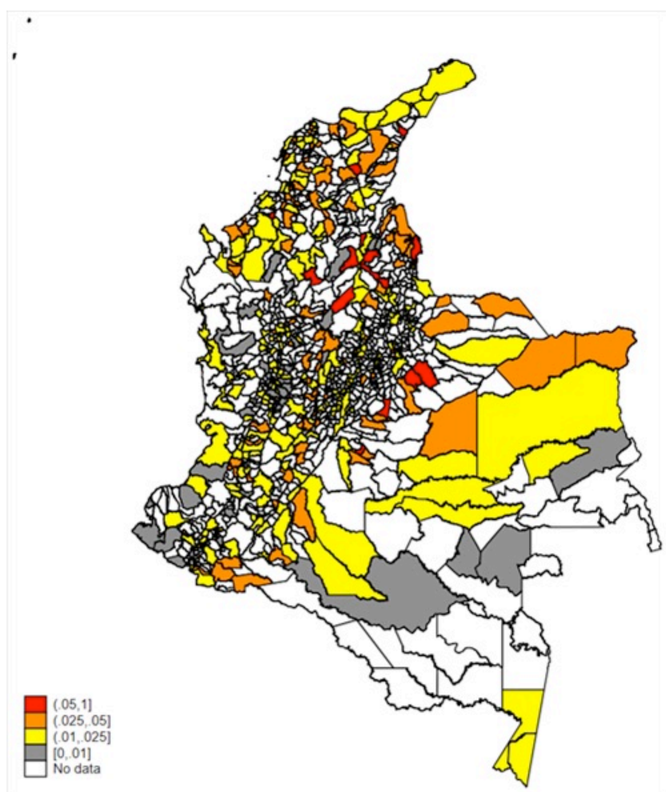


Figure 10: Municipal average of in-utero pollution exposure of children in DHS survey, Peru

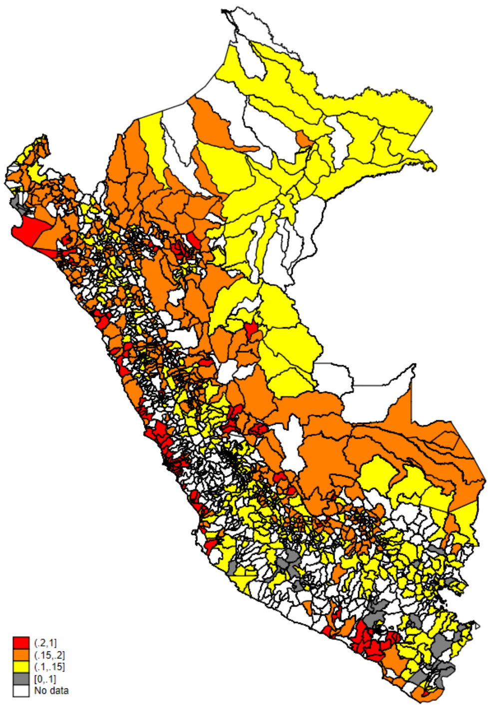


Figure 11: Municipal inter-quantile range of in-utero pollution exposure of children in DHS survey, Peru

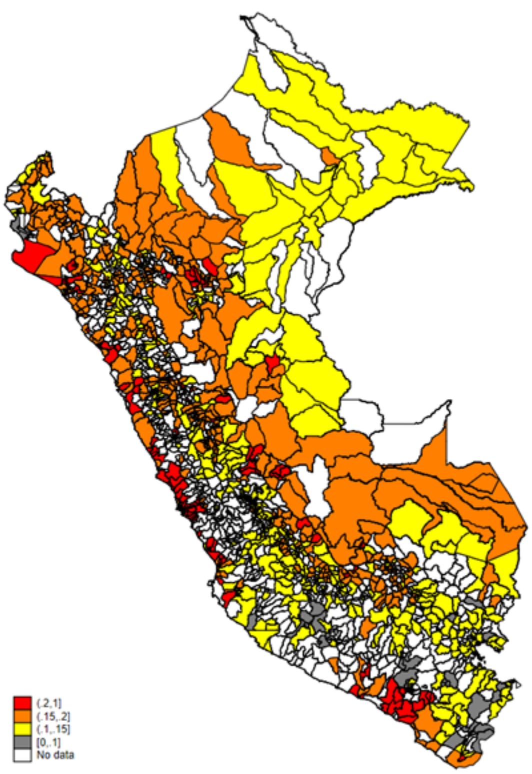
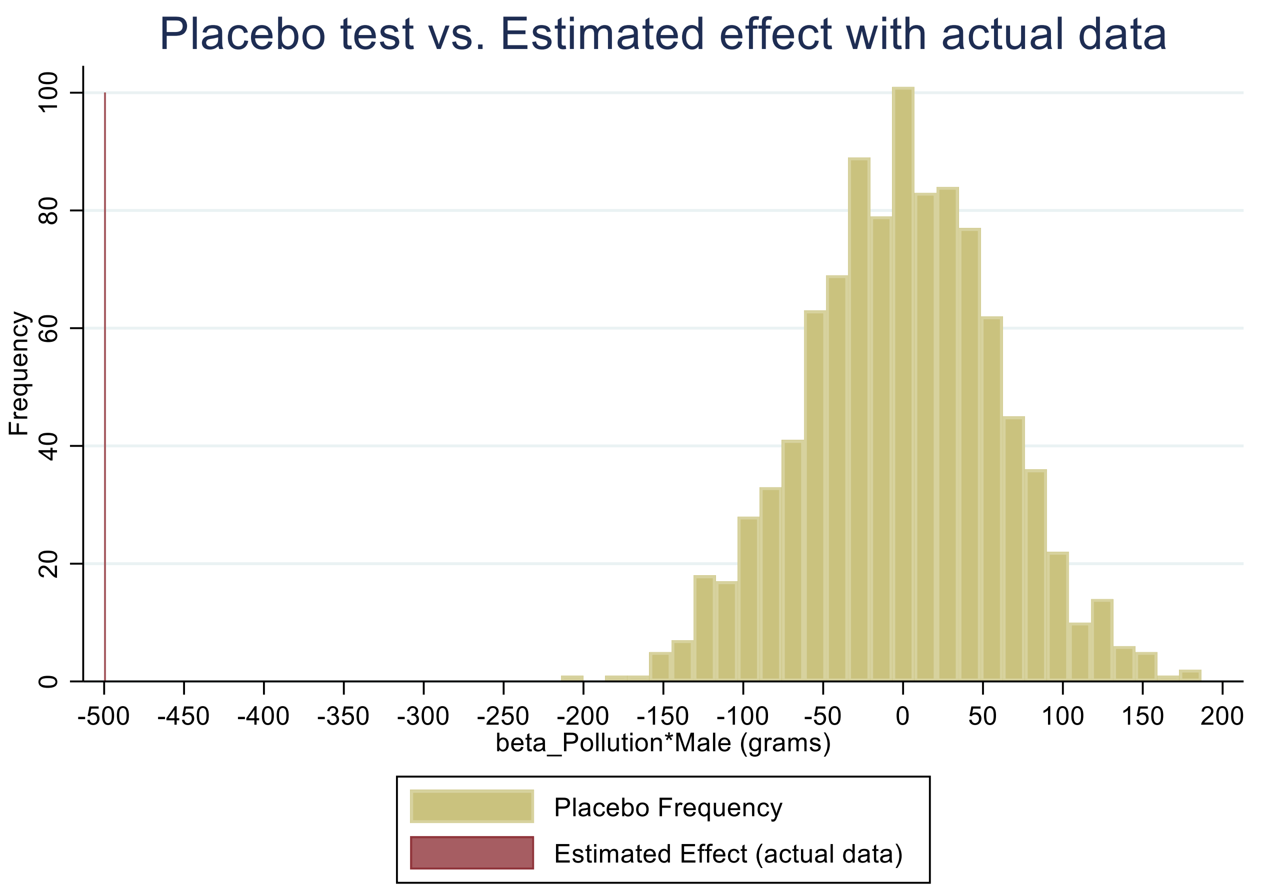


Figure 12: Montecarlo Simulation of placebo test



Tables

Table 1: Summary Statistics, DHS Survey

Panel A

Birth Weight

	Bolivia		Colombia		Peru	
	Girls	Boys	Girls	Boys	Girls	Boys
Percentiles						
5%	2,400	2,500	2,250	2,300	2,200	2,300
25%	3,000	3,000	2,800	2,996	2,800	2,950
50%	3,300	3,400	3,200	3,300	3,200	3,280
75%	3,600	3,800	3,500	3,600	3,500	3,620
95%	4,100	4,500	4,000	4,200	4,000	4,120
Mean	3,271	3,393	3,172	3,283	3,155	3,265
Std. Dev.	557	599	592	613	559	581
Obs	3,101	3,357	9,447	9,923	12,485	12,815

Panel B

Bolivia

Variable	Obs.	Mean	Std. Dev.	Min	Max
Low birth weight	6,458	0.05	0.23	0	1
Pollution	6,458	0.15	0.06	0.05	0.37
Current age of child	6,277	1.94	1.41	0	4.00
Male child	6,458	0.52	0.50	0	1
Child alive	6,458	0.97	0.17	0	1
Number of children under 5	6,458	1.61	0.79	0.00	6.00
Total children ever born	6,458	3.11	2.21	1.00	14.00
No migrant	6,457	0.87	0.33	0	1

Colombia

Variable	Obs.	Mean	Std. Dev.	Min	Max
Low birth weight	19,370	0.08	0.27	0	1
Pollution	19,004	0.19	0.04	0.07	0.41
Current age of child	19,167	1.62	1.34	0	4.00
Male child	19,370	0.51	0.50	0	1
Child alive	19,370	0.99	0.10	0	1
Number of children under 5	19,370	1.53	0.77	0.00	7.00
Total children ever born	19,370	2.32	1.54	1.00	14.00
No migrant	19,370	0.84	0.36	0	1

Peru

Variable	Obs.	Mean	Std. Dev.	Min	Max
Low birth weight	25,300	0.08	0.27	0	1
Pollution	25,280	0.16	0.05	0.03	0.79
Current age of child	24,891	2.02	1.40	0	4.00
Male child	25,300	0.51	0.50	0	1
Child alive	25,300	0.98	0.13	0	1
Number of children under 5	25,300	1.45	0.71	0.00	7.00
Total children ever born	25,300	2.80	1.90	1.00	15.00
No migrant	25,292	0.89	0.31	0	1

Table 2: Effect of pollution exposure in-utero on birth-weight (non-migrants)

VARIABLES	(1) Weight (grams)	(2) Weight (grams)	(3) Weight (grams)	(4) Weight (grams)
Pollution	575.0***	-274.4*	-130.7	86.39
	(57.65)	(157.3)	(169.3)	(261.3)
Male	114.0***	116.4***	116.0***	121.8***
	(5.395)	(5.087)	(5.775)	(11.99)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 3: Effect of pollution exposure in-utero on an indicator for low birth-weight (non-migrants)

VARIABLES	(1) Low birth-weight	(2) Low birth-weight	(3) Low birth-weight	(4) Low birth-weight
Pollution	-0.0875***	0.101*	0.0830	-0.00988
	(0.0259)	(0.0516)	(0.0630)	(0.116)
Male	-0.0184***	-0.0194***	-0.0189***	-0.0211***
	(0.00243)	(0.00244)	(0.00266)	(0.00598)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 4: Effect of pollution exposure in-utero on birth-weight, gender interaction (non-migrants)

VARIABLES	(1) Weight (grams)	(2) Weight (grams)	(3) Weight (grams)	(4) Weight (grams)
Pollution	717.6***	-122.4	12.18	352.6
	(79.93)	(164.8)	(180.5)	(291.8)
Male	161.4***	166.4***	162.4***	204.7***
	(19.20)	(19.11)	(21.56)	(41.66)
Pollution*Male	-279.5**	-294.2***	-272.5**	-499.4**
	(108.6)	(106.6)	(123.1)	(244.1)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 5: Effect of pollution exposure in-utero on an indicator for low birth-weight, gender interaction (non-migrants)

VARIABLES	(1) Low birth-weight	(2) Low birth-weight	(3) Low birth-weight	(4) Low birth-weight
Pollution	-0.132***	0.0502	0.0188	-0.114
	(0.0360)	(0.0562)	(0.0704)	(0.135)
Male	-0.0331***	-0.0360***	-0.0397***	-0.0536***
	(0.00864)	(0.00779)	(0.00949)	(0.0194)
Pollution*Male	0.0866*	0.0976**	0.122**	0.196*
	(0.0488)	(0.0434)	(0.0527)	(0.110)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers	-	-	-	38,526

Table 6: Effect of pollution exposure in-utero on gender (non-migrants)

	(1)	(2)	(3)	(4)
VARIABLES	Male	Male	Male	Male
Pollution	0.0329	0.225	0.219	0.153
	(0.0509)	(0.307)	(0.139)	(0.298)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 7: Placebo Random Pollution exposure (weight)

VARIABLES	(1) Weight (grams)	(2) Weight (grams)	(3) Weight (grams)	(4) Weight (grams)
Pollution	-15.41	-13.91	0.371	-3.857
	(19.80)	(19.95)	(22.37)	(41.99)
Male	110.9***	111.7***	114.4***	123.4***
	(11.49)	(11.60)	(12.56)	(25.54)
Pollution*Male	8.000	12.23	3.560	0.465
	(27.81)	(28.73)	(30.72)	(60.80)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 8: Placebo Random Pollution exposure (low birth weight)

VARIABLES	(1) Low birth-weight	(2) Low birth-weight	(3) Low birth-weight	(4) Low birth-weight
Pollution	0.0117	0.0112	0.00972	0.000711
	(0.00890)	(0.0108)	(0.0106)	(0.0239)
Male	-0.0212***	-0.0215***	-0.0203***	-0.0357***
	(0.00516)	(0.00554)	(0.00553)	(0.0128)
Pollution*Male	0.00792	0.00597	0.00426	0.0397
	(0.0125)	(0.0138)	(0.0137)	(0.0325)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers	-	-	-	38,526

Table 9: Monte Carlo Simulations of Placebo Tests (low birth weight)

Weight	(1) B_Pollution*Male	(2) _SE	(3) Rejection Rate	(4) B_Pollution*Male	(5) _SE	(6) Rejection Rate
Mean	0.319	29.814	0.044	-1.061	59.606	0.063
Std. Dev.	29.377	0.576	0.205	60.431	1.060	0.243
Min	-104.520	28.104	0	-214.025	55.944	0
Max	89.433	31.605	1	186.757	63.484	1
Control Variables						
First born	Yes	Yes	Yes	Yes	Yes	Yes
Month of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality *Yearbirth FE	Yes	Yes	Yes	No	No	No
Mother FE	No	No	No	Yes	Yes	Yes
Repetitions	1000					

Table 10: Monte Carlo Simulations of Placebo Tests (weight)

Low_birth_weight	(1)	(2)	(3)	(4)	(5)	(6)
	B_Pollution*Male	_SE	Rejection Rate	B_Pollution*Male	_SE	Rejection Rate
Mean	0.001	0.014	0.041	0.001	0.031	0.055
Std. Dev.	0.013	0.000	0.198	0.032	0.001	0.228
Min	-0.038	0.013	0	-0.094	0.028	0
Max	0.039	0.015	1	0.095	0.034	1
Control Variables						
First born	Yes	Yes	Yes	Yes	Yes	Yes
Month of birth FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipality *Yearbirth FE	Yes	Yes	Yes	No	No	No
Mother FE	No	No	No	Yes	Yes	Yes
Repetitions	1000					

Table 11: Controlling for first born child (weight)

VARIABLES	(1) Weight (grams)	(2) Weight (grams)	(3) Weight (grams)	(4) Weight (grams)
Pollution	731.6***	-122.7	10.43	371.2
	(79.71)	(163.5)	(180.3)	(291.3)
Male	159.9***	164.3***	160.3***	199.9***
	(19.14)	(19.09)	(21.44)	(41.46)
Pollution*Male	-274.2**	-286.6***	-266.1**	-477.4**
	(108.3)	(106.7)	(122.5)	(242.9)
First born	-80.84***	-87.49***	-90.19***	-64.46***
	(5.561)	(5.515)	(5.934)	(12.56)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 12: Controlling for first born child (low birth-weight)

VARIABLES	(1) Low birth-weight	(2) Low birth-weight	(3) Low birth-weight	(4) Low birth-weight
Pollution	-0.134***	0.0509	0.0208	-0.119
	(0.0359)	(0.0561)	(0.0706)	(0.135)
Male	-0.0330***	-0.0358***	-0.0396***	-0.0522***
	(0.00863)	(0.00781)	(0.00950)	(0.0195)
Pollution*Male	0.0865*	0.0971**	0.122**	0.189*
	(0.0488)	(0.0435)	(0.0527)	(0.111)
First born	0.00756***	0.00848***	0.00970***	0.0179***
	(0.00251)	(0.00308)	(0.00283)	(0.00637)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 13: Effect of pollution exposure in-utero on an indicator for birth-weight (full sample including migrants)

VARIABLES	(1) Weight (grams)	(2) Weight (grams)	(3) Weight (grams)	(4) Weight (grams)
Pollution	622.5***	-198.8	-129.3	80.63
	(76.82)	(153.1)	(168.2)	(275.9)
Male	141.0***	142.5***	138.6***	195.0***
	(18.50)	(18.69)	(20.48)	(38.52)
Pollution*Male	-170.2	-173.4*	-151.6	-464.5**
	(104.4)	(103.0)	(115.9)	(225.8)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

Table 14: Effect of pollution exposure in-utero on an indicator for low birth-weight (full sample including migrants)

VARIABLES	(1) Low birth-weight	(2) Low birth-weight	(3) Low birth-weight	(4) Low birth-weight
Pollution	-0.112***	0.0629	0.0658	-0.0176
	(0.0348)	(0.0571)	(0.0660)	(0.131)
Male	-0.0255***	-0.0274***	-0.0300***	-0.0494***
	(0.00838)	(0.00803)	(0.00921)	(0.0184)
Pollution*Male	0.0476	0.0553	0.0690	0.180*
	(0.0473)	(0.0443)	(0.0512)	(0.104)
Control Variables				
Survey FE	Yes			
Month of birth FE	Yes	Yes	Yes	Yes
Year of birth FE		Yes		
Municipality FE		Yes		
Municipality *Yearbirth FE			Yes	
Mother FE				Yes
Observations	44,134	44,134	44,134	44,134
Number of municipalities		1,449		
Number of municipalities*Yearbirth			7,922	
Number of mothers				38,526

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