# Assessing the Impact of Ambient Air Pollution on Birth Outcomes: Evidence from Punjab, Pakistan.

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## CERTIFICATE

This is to certify that this thesis entitled: **"Assessing The Impact of Ambient Air Pollution on Birth outcomes: Evidence from Punjab, Pakistan"** submitted by Sumbal Naz Khattak is accepted in its present form by the Department of Environmental Economics, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfying the requirements for partial fulfillment of the degree in **Master of Philosophy in Environmental Economics**.

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(2016-18)

# DECLARATION

I, Sumbal Naz Khattak, PIDE2016FMPHILENV14, hereby declare that I have produced the work presented in this thesis, during the scheduled period of study. I also declare that I have not taken any material from any source except referred to wherever due that amount of plagiarism is within acceptable range. If a violation of HEC rules on research has occurred in this thesis. I shall be liable to punishable action under the plagiarism rules of the HEC.

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**Sumbal Naz Khattak**
**PIDE2016FMPHILENV14**

# Dedication

This work is dedicated to my beloved parents.

**Contents**

# ABSTRACT

Air pollution is one of the extreme ecological threat to the human wellbeing. Previous studies have provided proof that maternal exposure to air pollution throughout pregnancy increases the hazard of adverse birth outcomes. Exposure to air pollution throughout pregnancy and its impact on children in utero is an emerging literature. The current study aims to investigate the impacts of air pollutants i.e. $PM_{2.5}$, $SO_2$, CO, $NO_2$ and ozone on birth outcomes, especially birth weight and birth size, in various districts of Punjab, Pakistan. Using linear probability model, the results suggest that *in-utero* exposure to $PM_{2.5}$, $SO_2$, CO, $NO_2$ reduces the birth weight but ozone increases the birth weight. In case of birth size, the first four indicators of air pollution increased then the probability of smaller birth size whereas ozone reduces this probability.

## Chapter 01

# INTRODUCTION

In the past years, the awareness of people regarding conceivable health effects of air pollution has risen significantly. Numerous epidemiological studies have demonstrated that different pollution indicators like $PM_{2.5}$ $SO_2$, $O_3$ and $NO_2$ were related with the morbidity and expanded mortality of respirational and cardiac infections (Dominici et al. 2003). Recently many studies revealed that PM and ozone are reliably related with different health effects (Levy et al. 2005).

Air pollution is a rapidly developing ecological problem in recent decades, which has a real toxicological effect on impact on human wellbeing and the surroundings. The increase in air pollution is caused by the rapid boost in the combustion of fossil fuels to produce electricity, fuel our vehicles, the consumption of industrial plants and the housing sector. (Hammitt, J. K. and Zhou, Y., 2006). A large number of physical activities releases hazardous chemicals into the atmosphere, but in addition to anthropogenic activities it also contributes to poor air quality (Kampa, M. and Castanas, E., 2008).

Consumption and burning of plastic materials in open air and deforestation are the other most referred to reasons for bad air quality. On account of these practices, toxic substances have expanded into the air, which ominously influences and represents a danger to human wellbeing and the entire ecosystem. To the extend people are concerned, an air toxin can add to an upturn in loss of lives, a genuine disease prevalence and most importantly it can cause danger to human wellbeing currently and for the generations to come. (A Azam, B Zanjani, M Mood. 2016).

Toxics in the air cause difficulties in the normal functioning of human organs. The main toxic effects of exposure to poor air quality are primarily respiratory, cardiovascular, ophthalmological, dermatological, neuropsychiatric, hematological, immunological and reproductive systems, and are additionally connected with other unfavorable health effects, for example low birth weight (LBW) and stunting. (Witter, R., et al 2008). On the other hand, toxic substances are also dangerous for vulnerable groups, including children and the elderly, as well as for patients with respiratory and cardiovascular diseases (A Azam, B Zanjani, M Mood. 2016). The consequence of ecological toxins on kids' wellbeing is progressively perceived as substantial. (Faustman 2000, USA, EPA, 1996).

In 2012, according to World Health Organization, one in nine deaths were due to conditions related to air pollution. Out of those deaths, about 3 million are deducted only from atmospheric pollution. Air pollution influences all areas, surroundings, socio-economic groups and all age brackets. Although all the individuals residing in a particular territory are breathing in similar air but the only difference is that there are some critical topographical contrasts in the exposure to air pollution. Natives of Africa, Asia or the Middle East inhale various intensities of air toxins that are substantially higher than those living in other parts of the world. Around 90% of individuals inhale air that does not consent to the WHO air quality recommendations. (World Health Organization, 2016).

There is a scarcity of scientific studies in Pakistan to correlate air pollution with health effects, particularly with adverse outcomes at birth like low birth weight (LBW), premature births, and stillbirths. Numerous epidemiological studies suggest that contaminated air builds the danger of adverse outcomes at birth. Over 21% of infants conceived in Pakistan have less than 2500g of weight at the time of birth, which is characterized as low birth weight. During the Postpartum period, LBW is related to an expanded hazard of mortality, morbidity, micronutrient deficiency and weakening of psychomotor development. The main cause of low birth weight in Western society is due to maternal smoking and exposure to environmental tobacco smoke. It is reported that the prevalence of smoking is relatively lower in Pakistan (15%), while the utilization of firewood as fuel for domestic cooking practices is common in case of both rural and urban areas (> 53%) with the utilization of total biomass which exclusively includes forest wood, the residues left over after the harvesting of the crop and fertilizers is more than 70% (Gilani, SI and Leon, DA, 2013).

In recent years, SUPARCO (Pakistan Space and Upper Atmospheric Research Commission) has been monitoring some environmental and polluting poisons. In the recent research, to represent the different sources of pollution in major urban cities of Pakistan they have linked chemical mass balance and multivariate analysis strategy. Furthermore, it has been announced that the daily concentration of particulates in many urban areas has been discovered very often higher than the air quality standard in addition to the monsoon. Lead aerosols were also recognized from non-automotive sources (Parekh et al., 1987). Subsequently (Ghauri et al., 1994) showed that increased airborne contamination in most urban areas derived by the use of fossil fuels in vehicles in the form of coal and oil, coal-fired power plants, factories and concrete materials, paper and pulp mills, etc.

Exposure to contaminants that are important and continually exposed to small stages of pollutants in ambient airborne has expected much consideration because of the extensive variety of dangerous impacts of airborne toxins on the ecosystem and on healthiness (Pope et al., 2002). SUPARCO has embraced the study of air quality from 2003 to 2004 due to the activity carried out study fuel efficiency in road transport by FERTS. Which has produced some of the very polluted urban cities in the country, particularly in Punjab, such as Lahore and Rawalpindi. Although small industries are big concern which are in Lahore which is known as industrialized city and is highly polluted. On the other hand, the Rawalpindi district where is rare monsoon rainfall and irregular. Rawalpindi which is known for mechanical workshop, oil refinery and it is also industrial hub surrounded by military centers.

Air pollution levels in urban areas have exceeded safety limits or have reached threshold levels. Air quality is the more awful in Punjab and about 90% of the general population breathes air that does not follow the WHO quality guidelines. The health of women, mothers and children is crucial for development, as reflected in MDG 4 however it tells about reducing baby mortality and on other hand MDG 5 establishing Improving motherly wellbeing. Exposure to poor air quality, both in the uterus and during childhood, has an impact on long-term well-being. The development of human capital is a dynamic procedure and the poor quality of the air which influences the initial conditions of life would have long-term results in the results of future life. Infants conceived with LBW (low birth weight) face extreme healthiness and development problems it may enforce significant expenses on people. For instance, the anticipated expenses may be rise during delivery and other care expense which may be exceed $ 100,000 (in 2000 dollars), however there are chances of death of baby within one year of birth is about 1 in 5. In fact, most of the kids' weight between 2000-2100 grams is very low as compare to healthy child (Almond, D., Chay, K.Y. Furthermore, Lee, D.S., 2005). The studies also formed a relationship between LBW and hypertension, deafness, brainy palsy, visual impairment, lung cancer breathing disease in kids, and also with a decrease level of IQ, and it impacts the cognitive development. According to economic research for the health of baby birth weight is important measure which analysis the welfare of baby. While in other areas, birth weight is considered as an important output for any research of production analysis for the health of newborns and maternal behaviors that influence the health of children (Rosenzweig and Schultz 1983 Grossman and Joyce 1990). In different perspectives, the newborn's initial endowment substitute by the input of birth weight which is human capital for health. Constant opinion that studies have discovered babies with low birth weight tent to have less education performance, a worse reported well-being and a reduction in ability to work and performance as compare to other adults (Behrman, Rosenzweig and Taubman 1994). In general, we note that Low Birth Weight is given by different aspects: a preterm birth which decrease the fetal development amount at a static duration of pregnancy, also called IUGR (intrauterine growth retardation). Studies on etiology of birth weight proposes that ecological and inherent elements which is important for the fetal growth in the uterus levels.

## 1.1 Problem Statement

The air quality in Punjab is worse and the people living in this province are exposed to the deteriorated air quality. According to the World Air Quality Index, Air quality is considered to be good if it is between 0-50 $\mu g/m^3$, moderate if it is between 50-100 $\mu g/m^3$, from 100-150 is considered to be unhealthy for sensitive group (children/ unborn children), it is considered to be unhealthy for adults if it is in the range of 150-200 $\mu g/m^3$, very unhealthy if it is between 201-300 $\mu g/m^3$ and it is hazardous if the air pollution exceeds 300+ $\mu g/m^3$. The air pollution will not only affect the residents, but may also be harmful for the unborn children. Exposure to air pollution during pregnancy may therefore have detrimental effects on fetuses which in turn can have negative effects on birth outcomes. Endowment at birth is linked with adult's life socioeconomic outcomes. Hence, it is important to explore the link among birth outcomes and airborne contamination in Punjab, Pakistan because Pakistan is one of the most polluted country and the air pollution has significantly increased over time.

## 1.2 Research Question

Does exposure to air pollution result in a negative impact on birth outcomes across different districts (Lahore, Multan, Bahawalpur, Muzaffargarh, Rawalpindi, Faisalabad, Sheikhupura, Gujranwala and Gujrat) of Punjab, Pakistan?

## 1.3 Objective of the Study

To estimate the impact of various indicators of air pollution (e.g. CO, $NO_2$, $PM_{2.5}$, $SO_2$ and $O_3$) on birth outcomes in Punjab, Pakistan.

## 1.4 Significance of the Study

This study is the contribution to the emerging literature of air pollution and its association with birth outcomes. To my knowledge, this is the first study in Pakistan examining the consequences of various indicators of air pollution on birth outcomes. The study is not only helping identify the severe aftermath of air pollution on the vulnerable group of the society (i.e. children) but also help identify the potential indirect health cost. Hence, it helps the policy makers in formulating and implementing the environment protecting regulations, especially with the aim of improving children health.

## 1.5 Organization of the Study:

The first chapter which consist of Introduction and the background of the topic, and further it includes the research question, the problem statement, objectives of the study and the significance of the study. The second chapter provides an overview of the literature related to maternal health affected by poor air quality. Third chapter will explain the potential biological channels through which air pollution is adversely affecting the birth outcomes. Fourth chapter will describe the data, variables and the econometric methodology that is used for the empirical analysis of the study. Fifth chapter will discuss the results and the sixth chapter will consist of the conclusion, policy implications, and the limitations of the study.

# Chapter 02

# THEMATIC REVIEW OF LITERATURE

## 2.1 Air Pollution and Health

There is broad confirmation that surrounding air pollution influences human health (Pope et al. 2002). There are many researches which have concentrated on adult's morbidity and mortality due to the air contamination impacts (Dockery et al. 1993). However, some age groups have all the susceptible than others. For instance, the effects are larger in the old ones as compare to adults in general (Saldiva et al. 1995). Symptoms of outdoor air pollution are across the board from eye problem, persistent cough, sore throat, running nose as well as difficulty in breathing, tightening of the chest and worsening of existing lung and heart and height issues (Joachim et al 2000). Air contamination has been implicated in worsen conditions like asthma, pneumonia, acute respiratory diseases, tuberculosis and airborne tumors (Nigel et al 2000).

Studies on the health hazards of children, like asthma or respirational symptoms, recommend which are opposing the age group which are also in danger due to air contamination than the over-all community (Heinrich et al., 1999)). Further the "conventional" endpoints in kids, while currently indication pregnancy outcomes is at high risk because of air pollution (Maisonet et al., 2004).

## 2.2 Air Pollution and Children's Health

The healthiness impacts of exposure to airborne pollutants have been widely reported and investigated in several papers (HEI, 2010). While the healthiness special effects of aged exposure can't be dismissed, air pollutants are more dangerous for kid as compare to adults (Kulkarni and

Grigg, 2008); thus, the concern of health is the first priority. While the children aged between 8-10 years have more chances of cough, respirational disease, rhinitis and other diseases due to the more frequently outdoor air pollution exposure to these children. (Peter et al 1998), and moreover, high mortality and morbidity was found in a slum area contrasted with middle class area crediting the differences to environmental pollution (Soman 1991 et al). By the review of published papers on impacts of contaminated air on health of young kids demonstrate that airborne pollution single and other factors of environment adversely affect children and adolescents paying little heed to their present fitness position (Raizenne et al., 1998).

It is confirming the impacts happen due to air concentration usually (Raizenne et al., 1998). Also, in studying exposure amid childhood we might have the capacity to evaluate and anticipate its effects on bodily growth and healthiness in maturity and adulthood (Blackwell et al., 2001). The increments in toxin consumption amid physical movement (Basrur, 2003) are specific worries. In spite of the fact that the system of kids' higher vulnerability to airborne contaminants are not yet surely known (Kulkarni and Grigg, 2008).

## 2.3 Air Pollution and Birth Weight and Birth Size

Due to the environmental factors and other toxic contaminates low birth weight is perceived (Ha, E.H., Hong, Y.C., Lee, B.E., Woo, B.H., Schwartz, J. what's more, Christiani, D.C., 2001.) The potential impacts of airborne toxins were inspect in small case control on birth weight first by Alderman et al. (1987); while this research could not find any connection between community air pollutants amid low birth weight and pregnancy. Last few decades the investigation and research have discovered new factors. While Wang et al. (1997) inspected the impacts of air pollutants on birth weight in contaminated site of China. In a multivariate analysis different range of potential confounding factors were adjusted. An evaluated measurements impact association was discovered amid the third trimester new born child birth weight among the maternal exposure to TSP and $SO_2$. Pre-birth presentation to smoke by the tobacco has been connected with deficiencies during the age of 3 those deficiencies are in birth size and birth weight (Ludwig 1994; Martinez et al. 1994; Sexton et al. 1990).

In 2001 Bobak et al. tried the speculation which show that airborne contamination is identified with Low Birth Weight from a British 1946 partner on time series data. Through which it is discovered that there is a strong connection among airborne contamination and birth weight record in perspective of coal usage. In the wake of controlling for different potential bewildering factors, babies considered in the most contaminated domains (yearly mean centralization of smoke > 281 pg/$m^3$) were by and large 82 g (95% CI, 24-140) these are the lighter more than imagined in fresh air zones (average smoke focus < 67 pg/$m^3$), after that Chen et al. (2002) in (USA) from 1991 through 1999 inspected the connection among birth weight and $O_3$, $PM_{10}$ and CO in northern Nevada. The outcomes recommended that the average $PM_{10}$ which increase by 10-µg/$m^3$ focuses in the midst of diminishing of birth weight of 11 g (95% CI, 2.3-19.8) connection with the 3rd trimester of pregnancy. In the event that low birth weight and smaller birth size is connected with airborne contamination, cutting down the groupings of airborne contamination could reduce the related prosperity stack essentially. (Schwartz, J. B.H.,. in addition, D.C Christiani., 2001.)

## 2.4 Air Pollution on Stillbirth

The World Health Organization has assessed that air pollution from strong fuel utilize air pollution represented 2.7% of the worldwide weight of disease in 2000 (Smith, K.R et al 2004), with 1.5 million overabundance deaths in 2002 (World Health Organization, 2006). Such estimates depend on the connection between air pollution and intense lower respiratory infections (kids <5 years old) and chronic obstructive lung disease (adults) and lung tumor. In any case, it is confirm that air pollution additionally builds the risk of other health conditions, including unfavorable pregnancy results (Smith, K.R. 2002). Pregnancy results including fetal mortality, LBW (low birth weight), intrauterine growth, little for gestational stage, retardation, and birth defects have been connected to introduction to used smoke (Leonardi-Bee et al. 2008) and air pollution (Šrám, R.J et al. 2005).

Unfriendly pregnancy results were excluded in the 2000 number of disease estimates for air pollution as a result of the scarcity of epidemiologic evidence (Smith, K.R. 2002). A few examinations have analyzed the relationship between airborne contamination and unfavorable outcomes of pregnancy, and preterm birth also included (Ritz, B et al. 2007), LBW (low birth weight) and intrauterine restriction in growth (Rich, D.Q et al. 2009). Be that as it is known that the studies in which the relationship between surrounding air pollution and stillbirth have been analyzed are limited (Pereira, L.A et al. 1998), and the period(s) of incubation when air pollution on might be related with fetal death is also unclear.

## 2.5 Air Pollution and Preterm Birth

Air contamination is connected with extended bleakness and mortality for various wellbeing symptoms, including cardiovascular sickness, lung malignancy, serious respirational impurities, adverse outcomes of pregnancy and asthma (Kampa and Castanas 2008). Asymmetry in wellbeing results related with airborne contamination arises amongst individuals existing in less-salary nations looked at and high wage nations, and different level of public living in different progression. (O'Neill et al. 2008). The initial growing pregnancy period is believed to remain essential in deciding the health overall and long term growth (Proietti, E. Frey, U., Röösli, M., Latzin, P., 2013. Airborne contamination newborn result and amid pregnancy: an audit. Diary of airborne solution and aspiratory tranquilize conveyance, 26(1), pp.9-23)

Exposure of air pollution has been related to < 37 weeks growth (Preterm birth) and LBW (low birth weight) which is < 2,500 g, however the proof isn't yet adequate to set up causality right now (Šrám et al. 2005). A few studies have documented that rates of preterm birth are higher among ladies living in destitution than for higher-income women (Institute of Medicine, 2007). Low birth weight is a result of diminished length of development or potentially confined fetal growth in utero (Kramer 2003).

Society and research indicate that embryo and newborn child are further delicate more than grownups to various air pollutants, as well as polycyclic, smoke by tobacco (ETS), pesticides and sweet-smelling hydrocarbons (PAHs) (WHO 1986; Perera 1995). Both rashness and development quarantine make basic commitment to mortality and morbidity amid beginning phases, these condition in long run might put grown-ups in danger for an extensive variety of adversarial health results (Longo et al. 2013). In 2009, around 12% of babies conceived in the U.S. were premature and approximately 8% were classified as low birth weight (Martin et al., 2011).

Air toxins might be a piece of composite set of components that expands the danger of LBW and preterm birth by procedures identified with aggravation, oxidative pressure, endocrine interruption, and weakened transport of oxygen over the placenta (Slama et al. 2008). Introduction to air elements with measurement ≤ 2.5 μm ($PM_{2.5}$) is of specific relevence in connection to results of pregnancy. The elements mostly breathed in profound areas within the lung, and oxidases pressure while irritation might be amongst machinelike paths by which presentation to these contaminations may add to beginning of preterm labor (Slama et al. 2008). Moreover, past studies demonstrates further spatially fine particles are similar more than different contaminants, and open air estimations of mentioned elements may fill in as a valuable intermediary record of individual introduction to a variety of contaminants (Sarnat et al. 2005).

We speculate that there might be a reduced in utero oxygen supply, coming about due to a decline of oxygen-passing on cutoff or blood thickness changes instigated through airborne contamination. CO instantly crosses the placenta to reveal the hatchling in utero driving a snappy gathering of carboxyhemoglobin and reducing the oxygen conveying limit of the blood. Another probability of formation of radicals which are free incited through air contamination may reason an incendiary response, adding to overhauled blood thickness. The cause can change consistency of Problematic placenta perfusion from blood to unfavorable results of pregnancy, which consist of preterm birth and low birth weighti. (Schwartz, J. Woo, B.H.,. furthermore, D.C Christiani,., 2001).

In this literature review, we have discussed all the possible adverse birth outcomes but we will only stick to birth weight and birth size because the low birth weight and smaller birth size are important predictor of the health and survival chances of the baby born.

### 2.6 Research Gap Identification

The literature shows that, there is no specific study in Pakistan that has focused on different dimensions of birth outcomes against diverse kinds of environmental disseminate and other socio-economic factors. Although, studies on the relationship of water quality and child health in Pakistan are available, there is a lack of studies associating air pollution with different indicators of child health and birth outcomes (e.g. Low birth weight and small birth size)

This study will investigate that how increasing air pollution affects the health of children. Does it contribute to the adverse birth outcomes? And what is the effect of airborne contamination on newborn’s birth weight and birth size? Looking into these dimensions against the air pollution and other socio economic indicators will make this study a significant contribution to current literature.

## Chapter 03

# AIR POLLUTION AND ADVERSE BIRTH OUTCOMES: POTENTIAL CHANNELS

Nowadays, airborne contamination is an essential reason or hazard issue for propagative health. It has been an alarming situation regarding unfavorable impacts on birth outcomes of airborne contamination, for example, Intrauterine growth restriction (IUGR), low birth weight, preterm births and defects of birth (Lee BE et al. 2003). Researches on the potential influence of airborne contamination on the health of adults and children have been growing over the last decade. Numerous epidemiological researches have demonstrated that airborne effluence is related with expanded morbidity and mortality for different wellbeing markers, as well as cardiovascular ailment, lung illness, intense respiratory pollution, asthma, and pregnancy outcome. (Glinianaia et al. 2004). Air poisons may be a piece of a perplexing arrangement of issues that expands the danger for low birth weight and preterm birth through methods associated with aggravation, oxidative pressure, endocrine disturbance, and weakened oxygen conveyance over the placenta (Slama et al. 2008). Moreover, past researches inquires that various poisons are less homogeneous than fine particles, and open air contamination of mentioned elements might fill in as a profitable proxy index of individual contact to a variety of toxins (Sarnat et al. 2005). lui S. et all. (2003) evaluated the vaporous poisons CO (carbon monoxide), $O_3$ (ozone), $SO_2$ (Sulfur dioxide) and $NO_2$ (nitrogen dioxide) and discovered that just $SO_2$ and CO exposures during the time of pregnancy were connected with preterm birth. Later Kramer, M.S., 2003 and Longo et al. (2013) assessed that LBW (Low birth weight) is a result of decreased size of the gestation or limited fetal development in utero. Both prematurity and development confinement make criticalness commitment to morbidity and mortality all through beginning phases, and in the long term, these conditions may place grown-ups in peril for a broad assortment of troublesome wellbeing results. In Beijing, China, a contrary relationship was seen between gestational ages, total suspended particles (TSP) and sulfur dioxide ($SO_2$) focus through pregnancy. (Xu, X., Ding, H. moreover, Wang, X. 1995).

Researches have assessed biological mechanism of impact of airborne contamination on adverse outcomes of birth. Pollutants and suspected mechanisms are given below for better understanding of impacts.

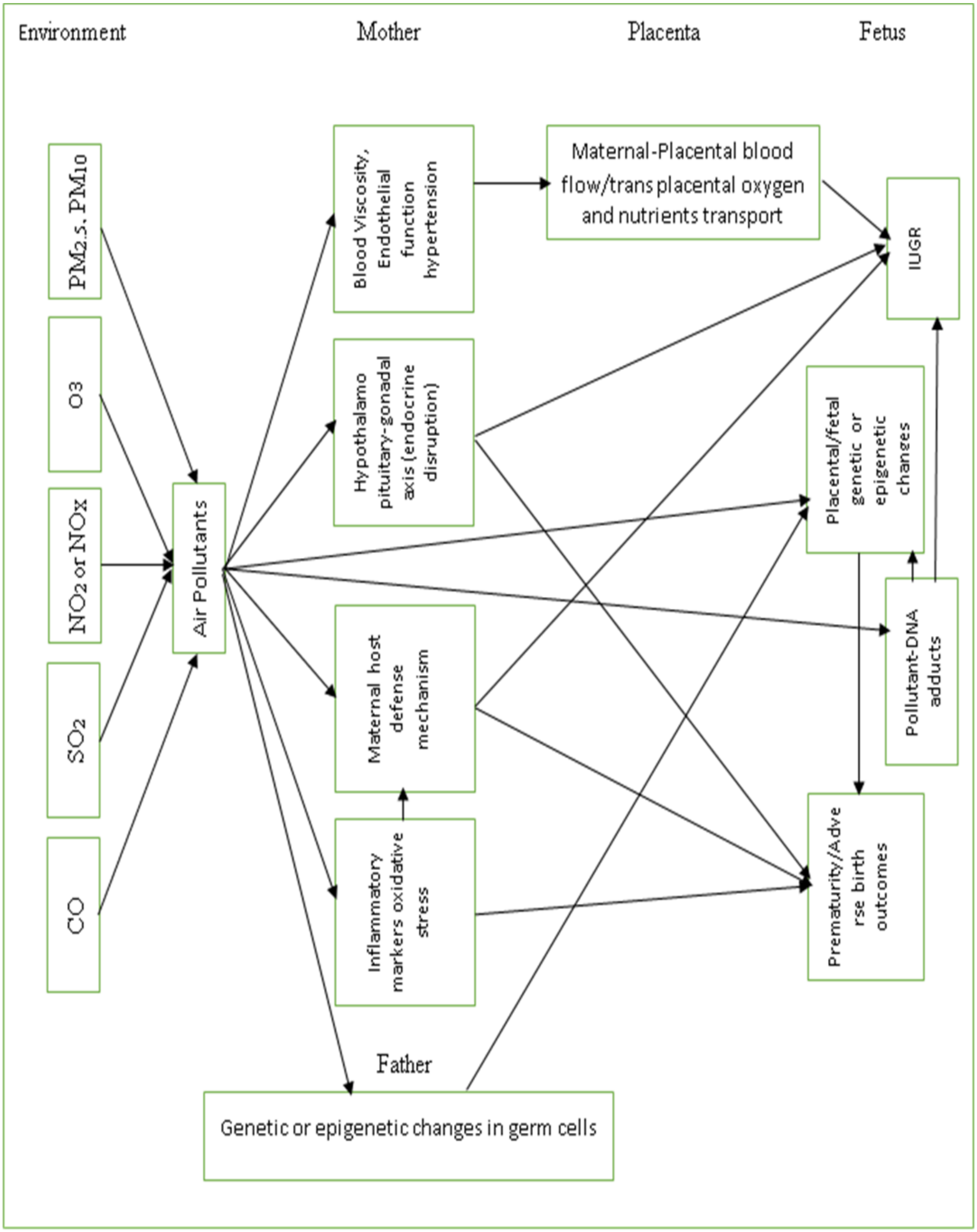
Pre-birth exposure to $SO_2$ can provoke progressive and concrete contaminations (Singh, 1989), it is examined that preeclampsia chance expanded bit by bit with quartiles of $SO_2$ introduction, amid the first trimester, second trimester and whole pregnancy (Ananth et al., 2013). $NO_2$ topples cancer prevention agents security frameworks of body of human being (Tabacova et al., 1998) and ambient air poisons, either independently or as proxies for the complicated mixture of urban air contamination, including $PM_{2.5}$, $PM_{10}$, CO, $O_3$, $NO_2$, and $NO_x$, have been worried to influence preeclampsia (Pedersen et al., 2014). Introduction of exploratory model to nitrogen dioxide ($NO_2$) all through prenatal period prompts lipid peroxidation in the placenta and hinders postnatal growth (Tabacova et al., 1985). Prologue to gas harms prompts provocative responses in the lung, provoking crucial landing of cytokines which might trigger PTB and SB (Walters et al., 2001). NO2 may in like manner have coordinate poison impacts on the baby (Maroziene and Grazuleviciene, 2002).

The human placenta is an organ located in the womb. It plays an immense function in the active conveyance of foods and metabolic wastes across the barrier dividing maternal and fetal compartments. Oxygen conveyance from maternal to fetal blood is a primary map of the placenta. It is unconvincingly important to import for the growing of a healthy fetus and to guarantee normal fetal development. The fetus is the name given to the developing immature that is besides located in the womb. Communication between the placenta and fetus is particularly important in order to do certain intrauterine growing deceleration is prevented. (Garnica AD and Chan WY, 1996) and when Carbon monoxide delays with the conveyance to fetus by oxygen by moving the oxygen disassociation curvature to one side showing relocation of oxygen from hemoglobin (Longo, 1977). Slower end of Carbon monoxide from fetuses contrasted with grownups can take with advanced collection stages (Koren et al., 1991). CO can likewise cause oxidative damage because of its impacts on the endothelium (Hardy and Thom, 1994). CO carbon monoxide stages created in vivo when people are presented to CO can make endothelial cells free nitric oxide and determined oxidants, and that these items can antagonistically influence cell physiology (Thom SR, et al. 2004).

In the previous decade, some researches have recognized a connection among air contamination and birth weight. These examinations basically center on the generally checked air toxins, including $NO_2$ (nitrogen dioxide), $O_3$ (ozone), CO (carbon monoxide), $PM_{2.5}$ (Particulate Matter), and sulfur dioxide ($SO_2$). Results from these examinations are conflicting as far as singling out a specific contamination that is reliably contrarily connected with birth weight or illustrating potential windows of weakness of the embryo by trimester of presentation (Glinianaia SV et al. 2004). Presentation to $O_3$ might has antagonistic impact on birth weight and neurodevelopment (Dell'Omo et al., 1995), in spite of the way that the framework through which ozone can impact pregnancy results are not clear.

$PM_{10}$ is transmitted from residential heating systems and power plants, however $PM_{2.5}$ is released from automobiles or firewood consuming. The two sorts of Particulate Matter incorporate essential and optional particles: essential particles are delivered straightforwardly from a source, for instance, improvement work; and auxiliary particles are encircled after response of essential particles noticeable all around with manufactured toxic substances, for instance, $SO_2$ or $NO_2$ (US Environmental Protection Agency, 2010). Primary fetal prologue to Particulate Matter can incite to modify trophoblastic development and inadmissible vascularization of the placenta (Roberts et al., 1991). Additionally, when Particulate Matter enters the lungs it can be acclimatized into the blood, and would then have the capacity to diffuse into inaccessible organs. In light of their for the most part minimal size, Particulate Matter escapes phagocytosis (Ritz et al., 2007). Section of Particulate Matter into the body by this system may lead oxidative aggravation in lungs and distinctive organs, including the placenta, along these lines growing the powerlessness of the mother to go into preterm labor (Liu et al., 2003).

Whenever poisons, for instance, polycyclic aromatic hydrocarbons (PAH) are adsorbed onto the surface of Particulate Matter (Parker et al., 2005), Deoxyribonucleic acid adducts are molded. (Perera et al., 1999). A lot of Deoxyribonucleic acid adducts were connected with diminished gestational length (Liu et al., 2003), and a relationship has been seen between the adduct levels in the mother's and the newborn child's blood. A lot of PAH can meddle with sustenance of the infant by growing blood consistency, and decreasing the stream to the placenta and uterus. (Liu et al., 2003; Ritz et al., 2000).


Environment
Mother
Placenta
Fetus
$PM_{2.5}$, $PM_{10}$
O3
$NO_2$ or $NO_x$
$SO_2$
CO
Air Pollutants
Blood Viscosity, Endothelial function hypertension
Hypothalamo pituitary-gonadal axis (endocrine disruption)
Maternal host defense mechanism
Inflammatory markers oxidative stress
Maternal-Placental blood flow/trans placental oxygen and nutrients transport
IUGR
Placental/fetal genetic or epigenetic changes
Pollutant-DNA adducts
Prematurity/Adverse birth outcomes
Father
Genetic or epigenetic changes in germ cells

## Chapter 04

# DATA AND METHODOLOGY

### 4.1 Study Area

The highly developing ecological problems is deprivation of surrounding quality of air especially in metropolitan regions. Different reviews demonstrate the airborne contamination stages in urban communities are breaking safe limits or have achieved the edge levels. The highly significant problem in Punjab is quality of air, the largest province of Pakistan in terms of population (110 million), the availability of over the top SPM (Suspended Particulate Matter) in atmosphere. The significant cause of SPM are bricks and transfer of silt etc. due to vehicles, in-effective dust of streets, hoisted green zones, conveyance, and industry, brick kilns and scorching of solid waste. Surrounding air quality of major districts e.g. Lahore, Faisalabad, Rawalpindi, Gujranwala, Multan, Muzaffargarh, Sheikhupura, Gujrat and Bahawalpur are influenced by increase in air pollution. Presence of large amounts of suspended particulate matter all around is surely a matter of worry because of its genuine health implications in these districts particularly for mother and infants. There are number of cases identified of adverse birth outcomes in these districts.

The first round of MICS was completed in the area amid 2003-04 and second round amid 2007-08. Both surveys provides data on socio-economic variables at regions/tehsils level of the Punjab. We will use MICS (2011) for our study. It is a commonly illustrative of family units, ladies and kids, with an aggregate sample size of 102048. According to my knowledge this might be a first study to examine air contamination as a probable factor for birth weight that comprised information from overwhelmingly less average salary family units in various locale. An extra quality is the homogeneity of the outline and information accumulation over the Punjab through an institutionalized shape and preparing for information collection of data set.

### 4.2 Data and variables

Information on pregnancy and birth results alongside other children, mothers and family attributes were utilized from the Multiple Indicator Cluster Survey (MICS) (2011). MICS is a household survey methodology developed by the United Nations Children's Fund (UNICEF) that has been harmonized with other survey programs such as the Demographic and Health Surveys. This survey on households provides internationally comparable, statistically rigorous data on social development focusing in particular on the condition of kids and females. We will combine MICS (2011) data with the different indicators of air pollution for different districts of Punjab from the Compendium Environment (2015). These indicators include CO, $NO_2$, $PM_{2.5}$, $SO_2$ and $O_3$. We will also control for humidity and wind speed. CO is measured in $mg/m^3$, whereas $NO_2$, $SO_2$, $NO_2$, $PM_{2.5}$ is measured in $\mu g/m^3$. Humidity in terms of percentage (%) and wind speed in terms of M/sec.

The principle dependent variable incorporate birth weight and birth size. Birth weight is estimated in grams. If the weight at birth is less than 2500 grams, the child is assumed to be unhealthy. For the size during childbirth, moms were gotten some information about the size of the child at the time of birth (very small, below average, average, above average, very large). We will convert this variable into a dummy variable where the response will take the value of 1 if the child was very small or below average, and 0 otherwise.

The subjective measurement of the mother on the size of the child at delivery is highly correlated with birth weight (Blanc, A.K. and Wardlaw, T., 2005). Therefore, we will use it as a proxy when birth weight data is not available (Magadi, M., Madise, N., & Diamond, I. (2001).

Control variables include age, education, marital status, state of residence, number of pregnancies of mothers, husband's education and occupation, and family size, etc. Age is measured as the number of years. Education is measured as years of schooling. Marital status will take the value 1 if the mother is married, and 0 otherwise. Rural area will take the value 1. Occupation will be measured by the use of various dummies.

### 4.3 Empirical Methodology

We will estimate the effect of airborne contamination on birth outcomes using the following equation:

$$birth\ outcome_{id} = \alpha + \beta pollution_{d} + \gamma X_{id} + \varepsilon_{id}$$

Where,

Birth Outcome is the birth of child i in district d;

$Pollution_d$ is the level of pollution in district d; and

$X_{id}$ shows various child, mother and household characteristics. We will use linear probability model.

### 4.4 Description of Variables

The variable birth outcome, which is our main variable of interest. It includes birth weight and birth size of the newborn child. Birth weight is measured in grams. A baby is considered to be healthy, if the weight of newly born baby at birth is 2.5kg. According to the MICS (2011) data set the average birth weight is 3kg. The birth size is the subjective measure by the mother. This is an ordered variable with multiple categories (very small, smaller than average, average, larger than average, very large). The response took the value of 1 if the child was very small or smaller than average, and 0 otherwise. The average size of the new born baby is considered to be between 19 and 21 inches long.

Air pollution is taken as various indicators such as PM $_{2.5}$, $SO_2$, CO, $NO_2$ and ozone ($O_3$). The variable is continuous in nature. CO is measured in mg/m$^3$ while $NO_2$, $SO_2$, $NO_2$, PM2.5 is measured in µg/m$^3$. Humidity and wind speed are also controlled in the model. Humidity is measured in terms of percentage (%) and wind speed is measured in terms of M/sec. The data on air pollution across districts is given in Table 4.1.

**Table 4.1: Air Pollution Data Across Districts**

| DISTRICTS | HH1A | Ozone | $SO_2$ | CO | $NO_2$ | $PM_{2.5}$ | Humidity | Wind speed |
|---|---|---|---|---|---|---|---|---|
| Lahore | 18 | 19 | 36.6 | 1.3775 | 79.925 | 223.35 | 83.425 | 1.105 |
| Multan | 22 | 21.0133333 | 30.276667 | 1.3633333 | 64.333333 | 130 | 88.136667 | 0.9533333 |
| Bahawalpur | 1 | 17.7 | 29.65 | 2.5 | 123 | 254 | 86.45 | 0.7 |
| Muzaffargarh | 6 | 27 | 21 | 1.45 | 96.5 | 215.5 | 85.5 | 0.9 |
| Rawalpindi | 29 | 30.225 | 48.75 | 2.055 | 179.75 | 161 | 53.275 | 0.8425 |
| Faisalabad | 8 | 58.3333333 | 159 | 4.45 | 434 | 235 | 55.833333 | 1.44 |
| Sheikhupura | 21 | 30.13 | 66.2 | 0.21 | 115.5 | 133.5 | 74.4 | 1.65 |
| Gujranwala | 12 | 90.5 | 77.5 | 0.55 | 55 | 135.5 | 67.05 | 1.28 |
| Gujrat | 13 | 87 | 38.5 | 0.305 | 53 | 104 | 62.5 | 1.1 |

Age of mother is measured in number of years. The average age of mother is 29 years. The average age of the mother at the time of marriage is 20 years. This shows the trend of early marriages which can have implications on the fetus health and hence should be controlled in the analysis. In our analysis by marital status, we mean the women who are currently married. All others including widows, divorced and separated construct the non-married category here. If woman is currently married took value one otherwise zero. Mother’s education is taken in number of years, woman have received education, only from formal sources, like school, college etc. Same is the case with Father’s education, this variable is taken in number of years. Prenatal care means the number of visits to doctor during pregnancy. For the state of residence, two broad categories i.e. rural and urban are considered. Rural area took the value one and zero otherwise. The variable of income is taken as total household income per month. Family size means the number of total family members. Also we have controlled for the Body mass index of the mother which is an estimate of the body fat which is based on the weight (in kilograms) in connection to the height (in centimeters). A healthy BMI is in the range from 19 to 25.

## Chapter 05

# RESULTS AND DISCUSSIONS

In this chapter we will discuss the results of the regression analysis used for evaluating the impacts of ambient airborne effluence on birth outcomes. To achieve the objective of the study, we first present the descriptive statistics of the dependent and independent variables in Table 5.1.

### 5.1 DESCRIPTIVE STATISTICS

The table 5.1 shows the complete picture of the descriptive statistics of dependent variables i.e. Birth Weight and Birth Size. Different types of air pollution like Ozone, $SO_2$, CO, $NO_2$ and $PM_{2.5}$ are our variables of interest. Whereas, we are controlling for humidity and wind speed along with other various parents, child and household characteristics like mother's age, mother's education, age at the time of marriage, current marital status, total children, antenatal care, Body Mass Index of mother, area of residence, household income (wealth index quintiles) and father's education.

It is obvious from the table that the average birth weight is approximately 3 Kilograms (Kg), whereas 17% children have smaller size at birth. The average values of the various pollution measures are very high. The mean age of the mother in the sample is 29 years, whereas the average age at the time of marriage is 20 years. This shows the trend of early marriages which can have implications on the fetus health and hence should be controlled in the analysis. On the average, both parents have lower education in the sample. Parental education could potential affect their behavior during pregnancies. Hence, these must be taken into account in the analysis.

## Table 5.1: Descriptive Statistics

| VARIABLES | N | MEAN | SD | MIN | MAX |
|---|---|---|---|---|---|
| Weight at birth (grams) | 790 | 2995.587 | 829.4281 | 500 | 6500 |
| Size at birth | 6,585 | 0.168 | 0.374 | 0 | 1 |
| Ozone (μg/m$^3$) | 12,820 | 43.53 | 27.04 | 17.70 | 90.50 |
| $SO_2$ (μg/m$^3$) | 12,820 | 65.83 | 47.36 | 21 | 159 |
| CO (mg/m$^3$) | 12,820 | 1.835 | 1.411 | 0.210 | 4.450 |
| $NO_2$ (μg/m$^3$) | 12,820 | 156.5 | 136.2 | 53 | 434 |
| $PM_{2.5}$ (μg/m$^3$) | 12,820 | 184.0 | 51.25 | 104 | 254 |
| Humidity | 12,820 | 72.01 | 13.16 | 53.28 | 88.14 |
| Wind speed | 12,820 | 1.138 | 0.283 | 0.700 | 1.650 |
| Mother's age | 9,991 | 29.26 | 5.719 | 15 | 49 |
| Mother's education | 12,819 | 3.916 | 4.840 | 0 | 17 |
| Age at marriage | 9,944 | 20.33 | 4.12 | 10 | 42 |
| Current marital status | 12,820 | 0.768 | 0.422 | 0 | 1 |
| Total children | 12,820 | 2.690 | 2.347 | 0 | 18 |
| Antenatal care (visits) | 12,759 | 2.138 | 3.10 | 0 | 36 |
| Body mass index | 9,359 | -0.632 | 1.200 | -5 | 4.990 |
| Urban | 12,820 | 0.444 | 0.497 | 0 | 1 |
| Wealth index quintiles | 12,820 | 2.680 | 1.864 | 0 | 5 |
| Father's education | 12,820 | 2.552 | 1.480 | 1 | 9 |

## 5.2 IMPACT OF AIR POLLUTION ON BIRTH WEIGHT

In-utero contact to airborne contamination has long lasting welfare effects. Along with other health issues, low birth weight is a major concern as the new-born with low birth weight have a high risk of developing chronic health conditions and as well as having a higher risk of illnesses such as asthma. These children are more likely to have functional and educational limitations than the ones with normal birth weight. In this current research, we have separately examined the impact of various indicators of air pollution i.e. $PM_{2.5}$, $SO_2$, CO, $NO_2$ and ozone on the birth weight of the new born as explained below. In order to show the relationship among the airborne effluence indicators and birth weight, we estimate 3 models. The first model shows the results when air pollution is the only variable in the analysis and parents, child or household characteristics are not controlled. In model 2, we controlled for the parents, child or household characteristics but the district fixed effects are not included in the regression. In the third model, we controlled for parents, child and household characteristics as well as district fixed effects. The district fixed effects control for any unobserved heterogeneity across districts. Hence, Model 3 is our preferred specification.

**Table 5.2: Impact of $PM_{2.5}$ on Birth Weight**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| $PM_{2.5}$ (µg/$m^3$) | -1.046 | -1.976* | -2.494*** |
| | (1.128) | (1.002) | (0.643) |
| Constant | 3,183.883*** | 3,097.639*** | 3,945.575*** |
| | (196.594) | (852.033) | (881.868) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.003 | 0.073 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

Table 5.2 shows the results for $PM_{2.5}$. In case of $PM_{2.5}$, by looking at Model 3 we can clearly see the negative relationship between $PM_{2.5}$ and birth weight which depicts that wherever the concentration of $PM_{2.5}$ is higher the birth weight will be lower. The results in Model 3 shows that 1 microgram per cubic meter ($\mu g/m^3$) increase in $PM_{2.5}$ reduces the birth weight by 2.494 grams. This means that a 10 $\mu g/m^3$ increase in $PM_{2.5}$ will reduce the birth weight by 24.94 grams. Hence, the measure of environmental degradation can have severe impacts of fetuses.

We next examine the impact of $SO_2$ on birth weight in Table 5.3. Looking at the results of $SO_2$ in model 3, there is a statistically significant negative relationship between $SO_2$ and birth weight which shows that as the concentration of $SO_2$ increases in the air, the birth weight of new born babies will be decreased. An increase in 1 microgram per cubic meter ($\mu g/m^3$) of $SO_2$ will decrease the birth weight by 36.940 grams. That means if the concentration of $SO_2$ is increased to 10 $\mu g/m^3$ then the birth weight will drop to 369.40 grams. Hence, exposure to $SO_2$ during pregnancy is more dangerous compared to $PM_{2.5}$.

**Table 5.3: Impact of $SO_2$ on Birth Weight**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| $SO_2$ ($\mu g/m^3$) | -1.284 | -3.011 | -36.940*** |
| | (0.837) | (2.389) | (9.530) |
| Constant | 3,070.446*** | 2,923.806*** | 5,287.738*** |
| | (57.183) | (845.838) | (1,147.630) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.004 | 0.068 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

In order to investigate the impact of CO on birth weight, the results are reported in Table 5.4. The findings indicate that if CO concentration is raised in the atmosphere the birth weight of new born babies will be decreased. For example, 1 milligram per cubic meter (mg/m$^3$) CO will decrease the birth weight by 476.725 grams. That means if the concentration of CO is raised to 10 mg/m$^3$ then the birth weight will decrease to 4767.25 grams. Overall, the results suggest a strong negative relation between CO concentration and birth weight of the newborn.

**Table 5.4: Impact of CO on Birth Weight**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| CO (mg/m$^3$) | -84.213** | -107.561** | -476.725*** |
| | (25.585) | (38.512) | (122.987) |
| Constant | 3,134.368*** | 3,325.474*** | 5,507.708*** |
| | (68.436) | (859.441) | (1,195.124) |
| Observations | 790 | 755 | 755 |
| R-squared | 0.014 | 0.079 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

To investigate the impact of $NO_2$ on birth weight the estimated effects are mentioned in Table 5.5. The result shows that the babies born in areas where the $NO_2$ concentration is higher tend to have lower birth weight. An increase of 1 microgram per cubic meter (µg/m$^3$) in air reduces the birth weight is decline by 5.424 grams. Consequently, if the amount of $NO_2$ concentration is increased by 10 micrograms per cubic meter (µg/m$^3$), the birth weight will be reduced by 54.24 grams.

**Table 5.5: Impact of $NO_2$ on Birth Weight**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| $NO_2$ (μg/$m^3$) | -0.854*** | -1.517*** | -5.424*** |
| | (0.201) | (0.392) | (1.399) |
| Constant | 3,109.971*** | 3,506.055*** | 5,309.641*** |
| | (50.900) | (867.531) | (1,152.322) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.014 | 0.084 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

Table 5.6 documents whether ozone affects birth weight of babies or not? If yes, then is it positive or negative? To find the answer to this question we have estimated the regression analysis where we have ozone as our main variable of interest. The coefficient is positive but statistically insignificant in the first model. However, it become significant when the child, parents and household characteristics are controlled for. Interestingly, the size of the coefficient increases tremendously when we also account for the district fixed effects in Model 3. It shows that an increase of 1 microgram per cubic meter (μg/$m^3$) of ozone concentration in the atmosphere is associated with an increase of 155.240 grams in the birth weight. Hence, protecting the ozone layer is not only important for current residents but is also beneficial for the unborn children.

**Table 5.6: Impact of Ozone on Birth Weight**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Ozone (μg/m$^3$) | 2.136 | 6.266*** | 155.240*** |
| | (1.661) | (1.433) | (40.050) |
| Constant | 2,909.190*** | 2,628.781*** | -2,696.905* |
| | (88.959) | (684.010) | (1,279.962) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.005 | 0.084 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

## 5.3 IMPACT OF AIR POLLUTION ON BIRTH SIZE:

Next, we estimate the effect of airborne contamination on birth size. A larger quantity of live births in Pakistan happens to be in non-institutional setups, for the most part in homes. Because of that it is particularly implausible that the weight of these babies are recorded at the time of birth. As stated by Pakistan Demographic & Health Survey (PDHS) (2012-2013), just 12% of the children conceived amid the period 2007-2012 are weighted. This generates a selection bias and lifts a critical concern about the sample not being the genuine representative of the population planned to be scrutinized. This is the reason birth size is used as a proxy when the required information on birth weight is not accessible. As indicated by the literature a mother's subjective measure of a child's size at the time of birth is observed to be very much correlated with birth weight. (Blanc, A.K. and Wardlaw, T., 2005).

Hence, in this section we examine the impact of the same indicators of pollution on the smaller size at birth.

**Table 5.7: Impact of $PM_{2.5}$ on Birth Size**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| $PM_{2.5}$ (µg/$m^3$) | 0.001** | 0.001*** | 0.00013*** |
| | (0.000) | (0.000) | (0.0000132) |
| Constant | 0.089** | 0.227*** | 0.221*** |
| | (0.029) | (0.021) | (0.037) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.003 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

Table 5.7 shows the impact of $PM_{2.5}$ on birth size. All the three models shows the significant, positive association between $PM_{2.5}$ and the probability of small birth size. A 1 microgram per cubic meter (µg/$m^3$) increase in $PM_{2.5}$ in air will increase the probability of small birth size by 0.013% and 10 micrograms per cubic meter (µg/$m^3$) increase in $PM_{2.5}$ will increase the probability of small birth size by 0.13%. This is a significant increase given the fact that the mean value for $PM_{2.5}$ is 184 (µg/$m^3$).

Table 5.8 shows the impact of $SO_2$ on birth size. In the table, Model 3 shows the positive and statistically significant association between $SO_2$ and birth size which means that increase in $SO_2$ will also increase the probability of small birth size. More specifically, 1 microgram per cubic meter (µg/$m^3$) increase in $SO_2$ in air will increase the probability of small birth size by 0.2% and 10 micrograms per cubic meter (µg/$m^3$) increase in $SO_2$ will increase the probability of small birth size by 2%.

**Table 5.8: Impact of SO2 on Birth Size**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| $SO_2$ (µg/m$^3$) | -0.001 | 0.001** | 0.002** |
|  | (0.000) | (0.000) | (0.001) |
| Constant | 0.178*** | 0.250*** | 0.151** |
|  | (0.025) | (0.030) | (0.060) |
|  |  |  |  |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.000 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

We also analyzed the impact of CO on birth size. CO has a significant impact on birth size. This is shown in table 5.9. If concentration of CO in air is increased by 1 milligram per cubic meter (mg/m$^3$) it will increase the probability of small birth size by 2.5% and 10 milligram per cubic meter (mg/m$^3$) increase in CO will increase the probability of small birth size by 25%. This result is consistent with the one in Table 5.4 where there same increase in CO has a strong negative effect on birth weight.

**Table 5.9: Impact of CO on Birth Size**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| CO (mg/m$^3$) | 0.011 | 0.008*** | 0.025** |
|  | (0.006) | (0.002) | (0.010) |
| Constant | 0.149*** | 0.224*** | 0.140* |
|  | (0.019) | (0.027) | (0.064) |
|  |  |  |  |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.001 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

By analyzing the impacts of $NO_2$ on the birth size we come to the conclusion that $NO_2$ and the probability of smaller birth size are positively related. For example, 1 microgram per cubic meter (μg/$m^3$) increase in $NO_2$ in air will increase the probability of small birth size by 0.028% and 10 micrograms per cubic meter (μg/$m^3$) increase in $NO_2$ will increase the probability of small birth size by 0.28%.

**Table 5.10: Impact of $NO_2$ on Birth Size**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| $NO_2$ (μg/$m^3$) | 0.000 | 0.000*** | 0.00028 |
| | (0.000) | (0.000) | (0.000028) |
| Constant | 0.160*** | 0.214*** | 0.150** |
| | (0.020) | (0.027) | (0.060) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.000 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

In our analysis, the smaller birth size and birth weight are negatively correlated. Hence, if a variable is going to have a positive effect on birth weight, it is supposed to have a negative effect on small birth size. In Table 5.6, ozone had a positive and a significant effect on birth weight. Hence, we expect a significant negative effect of ozone on smaller birth size. And this indeed the case as shown in Table 5.11. It means that when the ozone concentration in air increases, the probability of smaller birth size decreases. Precisely, 1 microgram per cubic meter (μg/$m^3$) increase in ozone in atmosphere will decrease the probability of small birth size by 0.8% and a 10 micrograms per cubic meter (μg/$m^3$) increase in ozone will decrease the probability of small birth size by 8%.

**Table 5.11: Impact of Ozone on Birth Size**

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Ozone (μg/$m^3$) | -0.001* | -0.000 | -0.008** |
| | (0.000) | (0.000) | (0.003) |
| Constant | 0.194*** | 0.296*** | 0.568*** |
| | (0.024) | (0.036) | (0.112) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.002 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1: The standard errors are clustered at the district level. The controls included child's year and month of birth fixed effects, mother's age, education, marital status, age at marriage, body mass index, number of children ever born, number of time she received antenatal care; education of the household head; household wealth index, type of toilet facility in the house, and region of residence. District fixed effects control for time invariant unobserved heterogeneity across districts.

Overall, the results in Table 5.7 – 5.11 are consistent with those reported in Tables 5.2 – 5.6 in terms of sign and significance. The overall summary of the results is given in Table 5.12.

**Table 5.12: Summary of Results Based on Model 3**

| VARIABLES | Birth Weight | Birth Size |
|---|---|---|
| $PM_{2.5}$ (μg/$m^3$) | -2.494 | 0.00013 |
| $SO_2$ (μg/$m^3$) | -36.940 | 0.002 |
| CO (mg/$m^3$) | -476.725 | 0.025 |
| $NO_2$ (μg/$m^3$) | -5.424 | 0.00028 |
| Ozone (μg/$m^3$) | 155.240 | -0.008 |

## Chapter 06

# CONCLUDING REMARKS

According to World Health Organization (WHO), approximately 4.6 million individuals pass away every year due to the airborne contamination in the environment. Airborne contamination is a significant issue of the recent decades which poses extremely serious health risks. Poor air quality not only affects the adults in several destructive ways but is also very detrimental for the unborn babies. The greater the exposure of pregnant woman to the air pollution, the more likely she is to suffer from IUGR, which will increase health problems for the fetus and their life when they grow up.

As per our knowledge this is first research to examine airborne contamination as a potential threat to fetus health and estimate its impact on birth weight and birth size in Pakistan. We have observed the association among the birth size and birth weight with air pollutants. Mother is vulnerable during pregnancy due to air pollution bringing her into highest category of exposure which increases the risk of exposure of unborn babies.

Since the changing of living standard and rising industrial era human being have been exposed to different air pollutants. $PM_{2.5}$ released from common sources have a bigger volume and smaller surface per unit mass, these $PM_{2.5}$ particles produced by people, mostly due to burning of fossil fuels, may show a more unsafe impact. They penetrate further into the lungs, can interface with resistant cells, and even display fundamental impacts in the blood circulation system. These human-inferred particles have a higher rate of redox action, glutathione exhaustion, and heme oxygenase, conceivably prompting a higher rate of mitochondrial breakdown and hereditary epigenetic impacts. Throughout the pregnancy, these systems may bring about changed placental hemodynamics with resulting diminishment of supplements and oxygen supply which cause the lower Birth Weight and smaller birth size.

Our results confirm that various indicators of air pollutants such as $PM_{2.5}$, $SO_2$, CO and $NO_2$ has a strong negative and significant effect on birth weight. On the other hand, the ozone has positive and significant effect on birth weight. These findings were further validated examining the impacts on birth size. The first four indicators increased the probability of smaller birth size, whereas ozone reduces this probability. Overall these results confirmed the findings of the emerging literature showing detrimental effects of air pollution on child health. Adverse impact on early health is associated with later life socioeconomic and labor market outcomes. Hence, efforts to reduce air pollution would have long term welfare effects.

As discussed above, air contaminations have significant effect on birth weight and birth size. Consequently, as in other social insurance, it might be smarter to keep an illness from happening as opposed to curing it later. This finding may have suggestions for the outline of strategy measures or policy since it might be more critical to diminish the high level concentration of pollutants rather than spent money on disease cure. Women are therefore dependent on policy change to reduce the risk of their unborn baby from air pollution such as avoid highly polluting vehicles in urban areas. In the short run, however, some measures should be taken by the potential mothers such as they should reduce their risk of exposure, wearing air filtering masks etc during pregnancy.

This study also has a few limitations. First, we have taken a year average of the pollutants in the risk assessment instead of taking point specific exposure. The reason being lack of data about the pollution exposure at different times or trimester. Also we had some data discrepancy in timing, since the pollution data we are considering in from 2008 to 2010 and the birth data was collected in 2010. We therefore treated the average exposure as a proxy for long-term exposure. As it is said that pollution levels are correlated over the course of time, so the average pollution data will be representing the period in which the births were recorded. But if the pollution was increased in these districts during that time period, then the results we have estimated to check the impact of air pollution on the birth outcomes would be underestimated. Furthermore, there are some crucial times in the pregnancy where the fetuses are extremely vulnerable to the effects of air pollution. We did adjust our pollution estimates for seasonal alterations by controlling for wind speed and humidity, to help account for some of these issues. As we are using average pollution exposure data so we do not have the complete picture of the exposures during the whole year. And maybe because of that we are not able to capture the true exposure accurately. However, this study is first step in this direction and future studies should improve these estimated when more detailed and disaggregated data is available.

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# APPENDIX

## Table 1: Impact of $PM_{2.5}$ on Birth Weight

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| PM2.5 (µg/m3) | -1.046 | -1.976* | -2.494*** |
| | (1.128) | (1.002) | (0.643) |
| Age of woman | | 8.000 | 10.956 |
| | | (21.193) | (20.997) |
| Mother's education | | 10.782 | 11.463 |
| | | (6.443) | (6.757) |
| Marital Status | | -247.869 | -340.092 |
| | | (396.570) | (374.693) |
| Age at marriage | | 4.818 | 2.182 |
| | | (18.605) | (18.747) |
| Mother's Body Mass Index | | 64.679** | 61.889** |
| | | (19.522) | (19.566) |
| Total children | | 20.792 | 4.102 |
| | | (55.643) | (54.911) |
| Antenatal care (visits) | | 17.052*** | 17.307*** |
| | | (3.385) | (3.237) |
| Education of household head = 2, Primary | | -124.066 | -111.904 |
| | | (157.874) | (153.180) |
| Education of household head = 3, Middle | | -44.017 | -36.390 |
| | | (139.263) | (133.102) |
| Education of household head = 4, Secondary | | -73.219 | -46.581 |
| | | (116.778) | (107.891) |
| Education of household head = 5, Higher | | -162.569 | -118.324 |
| | | (104.171) | (100.877) |
| Area | | 86.285 | 139.788** |
| | | (63.223) | (52.682) |
| Humidity (%) | | 2.514 | 1.046 |
| | | (3.122) | (1.974) |
| Wind speed (m/sec) | | -62.077 | -471.017*** |
| | | (270.945) | (122.399) |
| Constant | 3,183.883*** | 3,097.639*** | 3,945.575*** |
| | (196.594) | (852.033) | (881.868) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.003 | 0.073 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Table 2: Impact of $SO_2$ on Birth Weight

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| SO2 (µg/m3) | -1.284 | -3.011 | -36.940*** |
| | (0.837) | (2.389) | (9.530) |
| Age of woman | | 5.567 | 10.956 |
| | | (21.248) | (20.997) |
| Mother's | | 10.849 | 11.463 |
| | | (6.779) | (6.757) |
| Marital Status | | -226.058 | -340.092 |
| | | (395.764) | (374.693) |
| Age at marriage | | 6.873 | 2.182 |
| | | (18.808) | (18.747) |
| Mother's Body Mass Index | | 63.742*** | 61.889** |
| | | (18.997) | (19.566) |
| Total Children | | 25.339 | 4.102 |
| | | (55.127) | (54.911) |
| Antenatal care (visits) | | 15.986*** | 17.307*** |
| | | (3.308) | (3.237) |
| Education of household head = 2, Primary | | -115.762 | -111.904 |
| | | (156.486) | (153.180) |
| Education of household head = 3, Middle | | -26.561 | -36.390 |
| | | (139.885) | (133.102) |
| Education of household head = 4, Secondary | | -66.605 | -46.581 |
| | | (114.126) | (107.891) |
| Education of household head = 5, Higher | | -145.806 | -118.324 |
| | | (99.055) | (100.877) |
| Area | | 78.040 | 139.788** |
| | | (67.240) | (52.682) |
| Humidity (%) | | -3.081 | -20.949** |
| | | (5.262) | (6.322) |
| Wind speed (m/sec) | | 236.779 | 987.592** |
| | | (459.225) | (295.501) |
| Constant | 3,070.446*** | 2,923.806*** | 5,287.738*** |
| | (57.183) | (845.838) | (1,147.630) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.004 | 0.068 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Table 3: Impact of CO on Birth Weight

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| CO (mg/m3) | -84.213** | -107.561** | -476.725*** |
| | (25.585) | (38.512) | (122.987) |
| Age of woman | | 8.034 | 10.956 |
| | | (21.348) | (20.997) |
| Mother’s Education | | 11.443 | 11.463 |
| | | (6.440) | (6.757) |
| Marital status | | -199.567 | -340.092 |
| | | (384.376) | (374.693) |
| Age at marriage | | 5.314 | 2.182 |
| | | (18.754) | (18.747) |
| Mother’s Body Mass Index | | 62.120** | 61.889** |
| | | (19.306) | (19.566) |
| Total Children | | 18.770 | 4.102 |
| | | (56.490) | (54.911) |
| Antenatal care (visits) | | 16.377*** | 17.307*** |
| | | (3.429) | (3.237) |
| Education of household head = 2, Primary | | -110.845 | -111.904 |
| | | (151.386) | (153.180) |
| Education of household head = 3, Middle | | -28.233 | -36.390 |
| | | (135.490) | (133.102) |
| Education of household head = 4, Secondary | | -71.022 | -46.581 |
| | | (115.069) | (107.891) |
| Education of household head = 5, Higher | | -145.632 | -118.324 |
| | | (98.575) | (100.877) |
| Area | | 108.021 | 139.788** |
| | | (66.089) | (52.682) |
| Humidity (%) | | -2.599 | -3.369 |
| | | (4.060) | (2.444) |
| Wind speed (m/sec) | | -96.835 | -1,359.817*** |
| | | (260.463) | (331.303) |
| Constant | 3,134.368*** | 3,325.474*** | 5,507.708*** |
| | (68.436) | (859.441) | (1,195.124) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.014 | 0.079 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## Table 4: Impact of $NO_2$ on Birth Weight

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| NO2 (μg/m3) | -0.854*** | -1.517*** | -5.424*** |
| | (0.201) | (0.392) | (1.399) |
| Age of woman | | 8.749 | 10.956 |
| | | (21.181) | (20.997) |
| Mother's Education | | 11.635 | 11.463 |
| | | (6.409) | (6.757) |
| Marital Status | | -212.147 | -340.092 |
| | | (376.899) | (374.693) |
| Age at marriage | | 4.769 | 2.182 |
| | | (18.659) | (18.747) |
| Mother's Body Mass Index | | 61.721** | 61.889** |
| | | (19.334) | (19.566) |
| Total Children | | 15.739 | 4.102 |
| | | (56.349) | (54.911) |
| Antenatal care (visits) | | 16.436*** | 17.307*** |
| | | (3.451) | (3.237) |
| Education of household head = 2, Primary | | -108.891 | -111.904 |
| | | (150.702) | (153.180) |
| Education of household head = 3, Middle | | -28.892 | -36.390 |
| | | (134.518) | (133.102) |
| Education of household head = 4, Secondary | | -68.637 | -46.581 |
| | | (113.639) | (107.891) |
| Education of household head = 5, Higher | | -139.962 | -118.324 |
| | | (97.791) | (100.877) |
| Area | | 122.972* | 139.788** |
| | | (61.914) | (52.682) |
| Humidity (%) | | -6.243 | -14.919** |
| | | (4.413) | (4.866) |
| Wind speed (m/sec) | | 64.862 | -399.981*** |
| | | (251.934) | (109.290) |
| Constant | 3,109.971*** | 3,506.055*** | 5,309.641*** |
| | (50.900) | (867.531) | (1,152.322) |
| Observations | 790 | 755 | 755 |
| R-squared | 0.014 | 0.084 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Table 5: Impact of Ozone on Birth Weight

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Ozone (µg/m3) | 2.136 | 6.266*** | 155.240*** |
| | (1.661) | (1.433) | (40.050) |
| Age of woman | | 9.555 | 10.956 |
| | | (20.906) | (20.997) |
| Mother's education | | 9.905 | 11.463 |
| | | (6.683) | (6.757) |
| Marital status | | -298.551 | -340.092 |
| | | (402.280) | (374.693) |
| Age at marriage | | 3.386 | 2.182 |
| | | (18.288) | (18.747) |
| Body Mass Index | | 62.354** | 61.889** |
| | | (19.338) | (19.566) |
| Total Children | | 9.688 | 4.102 |
| | | (55.003) | (54.911) |
| Antenatal care (visits) | | 18.615*** | 17.307*** |
| | | (2.797) | (3.237) |
| Education of household head = 2, Primary | | -110.366 | -111.904 |
| | | (152.198) | (153.180) |
| Education of household head = 3, Middle | | -24.763 | -36.390 |
| | | (136.901) | (133.102) |
| Education of household head = 4, Secondary | | -53.613 | -46.581 |
| | | (112.891) | (107.891) |
| Education of household head = 5, Higher | | -129.241 | -118.324 |
| | | (97.797) | (100.877) |
| Area | | 82.286 | 139.788** |
| | | (70.880) | (52.682) |
| Humidity (%) | | 6.082** | 47.848*** |
| | | (2.572) | (11.893) |
| Wind speed (m/sec) | | -376.959* | -1,592.209*** |
| | | (179.807) | (389.725) |
| Constant | 2,909.190*** | 2,628.781*** | -2,696.905* |
| | (88.959) | (684.010) | (1,279.962) |
| | | | |
| Observations | 790 | 755 | 755 |
| R-squared | 0.005 | 0.084 | 0.098 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## Table 6: Impact of $PM_{2.5}$ on Birth Size

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| PM2.5 (µg/m3) | 0.000** | 0.000*** | 0.000** |
| | (0.000) | (0.000) | (0.000) |
| Age of woman | | -0.002 | -0.002 |
| | | (0.003) | (0.003) |
| Mother's education | | -0.002* | -0.002* |
| | | (0.001) | (0.001) |
| Marital status | | 0.021 | 0.021 |
| | | (0.039) | (0.039) |
| Age at marriage | | 0.001 | 0.001 |
| | | (0.003) | (0.003) |
| Mother's Body Mass Index | | -0.024*** | -0.024*** |
| | | (0.006) | (0.006) |
| Total Children | | 0.003 | 0.004 |
| | | (0.008) | (0.008) |
| Antenatal care (visits) | | 0.001* | 0.001* |
| | | (0.000) | (0.000) |
| Education of household head = 2, Primary | | -0.016 | -0.018 |
| | | (0.011) | (0.011) |
| Education of household head = 3, Middle | | -0.016 | -0.017 |
| | | (0.011) | (0.011) |
| Education of household head = 4, Secondary | | 0.008 | 0.006 |
| | | (0.016) | (0.017) |
| Education of household head = 5, Higher | | 0.012 | 0.009 |
| | | (0.013) | (0.014) |
| Education of household head = 9, Missing/DK | | -0.048 | -0.050 |
| | | (0.084) | (0.085) |
| Area | | 0.007 | 0.005 |
| | | (0.023) | (0.023) |
| Humidity (%) | | 0.000 | 0.000 |
| | | (0.000) | (0.000) |
| Wind speed (m/sec) | | -0.039** | -0.043** |
| | | (0.014) | (0.018) |
| Constant | 0.089** | 0.227*** | 0.221*** |
| | (0.029) | (0.021) | (0.037) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.003 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

## Table 7: Impact of $SO_2$ on Birth Size

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| SO2 (µg/m3) | -0.000 | 0.000** | 0.002** |
| | (0.000) | (0.000) | (0.001) |
| Age of woman | | -0.002 | -0.002 |
| | | (0.003) | (0.003) |
| Mother's education | | -0.002* | -0.002* |
| | | (0.001) | (0.001) |
| Marital status | | 0.022 | 0.021 |
| | | (0.040) | (0.039) |
| Age at marriage | | 0.001 | 0.001 |
| | | (0.003) | (0.003) |
| Mother's Body Mass Index | | -0.024*** | -0.024*** |
| | | (0.006) | (0.006) |
| Total Children | | 0.003 | 0.004 |
| | | (0.008) | (0.008) |
| Antenatal care (visits) | | 0.001* | 0.001* |
| | | (0.000) | (0.000) |
| Education of household head = 2, Primary | | -0.017 | -0.018 |
| | | (0.011) | (0.011) |
| Education of household head = 3, Middle | | -0.016 | -0.017 |
| | | (0.011) | (0.011) |
| Education of household head = 4, Secondary | | 0.008 | 0.006 |
| | | (0.016) | (0.017) |
| Education of household head = 5, Higher | | 0.012 | 0.009 |
| | | (0.014) | (0.014) |
| Education of household head = 9, Missing/DK | | -0.049 | -0.050 |
| | | (0.083) | (0.085) |
| Area | | 0.009 | 0.005 |
| | | (0.023) | (0.023) |
| Humidity (%) | | 0.001* | 0.001** |
| | | (0.000) | (0.000) |
| Wind speed (m/sec) | | -0.073*** | -0.119*** |
| | | (0.016) | (0.019) |
| Constant | 0.178*** | 0.250*** | 0.151** |
| | (0.025) | (0.030) | (0.060) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.000 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Table 8: Impact of CO on Birth Size

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| CO (mg/m3) | 0.011 | 0.008*** | 0.025** |
| | (0.006) | (0.002) | (0.010) |
| Age of woman | | -0.002 | -0.002 |
| | | (0.003) | (0.003) |
| Mother's education | | -0.002* | -0.002* |
| | | (0.001) | (0.001) |
| Marital status | | 0.022 | 0.021 |
| | | (0.040) | (0.039) |
| Age at marriage | | 0.001 | 0.001 |
| | | (0.003) | (0.003) |
| Mother's Body Mass Index | | -0.024*** | -0.024*** |
| | | (0.006) | (0.006) |
| Total Children | | 0.003 | 0.004 |
| | | (0.008) | (0.008) |
| Antenatal care (Visits) | | 0.001* | 0.001* |
| | | (0.000) | (0.000) |
| Education of household head = 2, Primary | | -0.017 | -0.018 |
| | | (0.011) | (0.011) |
| Education of household head = 3, Middle | | -0.016 | -0.017 |
| | | (0.011) | (0.011) |
| Education of household head = 4, Secondary | | 0.007 | 0.006 |
| | | (0.016) | (0.017) |
| Education of household head = 5, Higher | | 0.011 | 0.009 |
| | | (0.013) | (0.014) |
| Education of household head = 9, Missing/DK | | -0.048 | -0.050 |
| | | (0.084) | (0.085) |
| Area | | 0.007 | 0.005 |
| | | (0.023) | (0.023) |
| Humidity (%) | | 0.000 | 0.000* |
| | | (0.000) | (0.000) |
| Wind speed (m/sec) | | -0.040** | 0.003 |
| | | (0.012) | (0.034) |
| Constant | 0.149*** | 0.224*** | 0.140* |
| | (0.019) | (0.027) | (0.064) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.001 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Table F: Impact of $NO_2$ on Birth Size

| VARIABLES | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| NO2 (µg/m3) | 0.000 | 0.000*** | 0.000** |
| | (0.000) | (0.000) | (0.000) |
| Age of woman | | -0.002 | -0.002 |
| | | (0.003) | (0.003) |
| Mother’s education | | -0.002* | -0.002* |
| | | (0.001) | (0.001) |
| Marital status | | 0.022 | 0.021 |
| | | (0.040) | (0.039) |
| Age at marriage | | 0.001 | 0.001 |
| | | (0.003) | (0.003) |
| Mother’s Body Mass Index | | -0.024*** | -0.024*** |
| | | (0.006) | (0.006) |
| Total Children | | 0.004 | 0.004 |
| | | (0.008) | (0.008) |
| Antenatal care (visits) | | 0.001* | 0.001* |
| | | (0.000) | (0.000) |
| Education of household head = 2, Primary | | -0.017 | -0.018 |
| | | (0.011) | (0.011) |
| Education of household head = 3, Middle | | -0.017 | -0.017 |
| | | (0.011) | (0.011) |
| Education of household head = 4, Secondary | | 0.007 | 0.006 |
| | | (0.016) | (0.017) |
| Education of household head = 5, Higher | | 0.010 | 0.009 |
| | | (0.013) | (0.014) |
| Education of household head = 9, Missing/DK | | -0.048 | -0.050 |
| | | (0.084) | (0.085) |
| Area | | 0.007 | 0.005 |
| | | (0.023) | (0.023) |
| Humidity (%) | | 0.001* | 0.001*** |
| | | (0.000) | (0.000) |
| Wind speed (m/sec) | | -0.053*** | -0.047** |
| | | (0.014) | (0.016) |
| Constant | 0.160*** | 0.214*** | 0.150** |
| | (0.020) | (0.027) | (0.060) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.000 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## Table F: Impact of Ozone on Birth Size

| VARIABLES | Model 1 | Model 2 | Model 2 |
|---|---|---|---|
| Ozone (µg/m3) | -0.001* | -0.000 | -0.008** |
| | (0.000) | (0.000) | (0.003) |
| Age of woman | | -0.002 | -0.002 |
| | | (0.003) | (0.003) |
| Mother's education | | -0.002* | -0.002* |
| | | (0.001) | (0.001) |
| Marital status | | 0.021 | 0.021 |
| | | (0.040) | (0.039) |
| Age at marriage | | 0.001 | 0.001 |
| | | (0.003) | (0.003) |
| Mother's Body Mass Index | | -0.024*** | -0.024*** |
| | | (0.006) | (0.006) |
| Total Children | | 0.003 | 0.004 |
| | | (0.008) | (0.008) |
| Antenatal care (visits) | | 0.001 | 0.001* |
| | | (0.000) | (0.000) |
| Education of household head = 2, Primary | | -0.017 | -0.018 |
| | | (0.011) | (0.011) |
| Education of household head = 3, Middle | | -0.017 | -0.017 |
| | | (0.011) | (0.011) |
| Education of household head = 4, Secondary | | 0.007 | 0.006 |
| | | (0.016) | (0.017) |
| Education of household head = 5, Higher | | 0.012 | 0.009 |
| | | (0.014) | (0.014) |
| Education of household head = 9, Missing/DK | | -0.047 | -0.050 |
| | | (0.083) | (0.085) |
| Area | | 0.010 | 0.005 |
| | | (0.023) | (0.023) |
| Humidity (%) | | -0.000 | -0.002* |
| | | (0.000) | (0.001) |
| Wind speed (m/sec) | | -0.043* | 0.016 |
| | | (0.019) | (0.038) |
| Constant | 0.194*** | 0.296*** | 0.568*** |
| | (0.024) | (0.036) | (0.112) |
| | | | |
| Observations | 6,585 | 6,191 | 6,191 |
| R-squared | 0.002 | 0.026 | 0.028 |
| Controls | NO | YES | YES |
| District FE | NO | NO | YES |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1