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The Effects of Air Pollution on Infant Health: An Empirical Evaluation of Georgia

Mamadou Laity Sow

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THE EFFECTS OF AIR POLLUTION ON INFANT HEALTH:

AN EMPIRICAL EVALUATION OF GEORGIA

BY

MAMADOU LAITY SOW

A dissertation submitted in partial fulfillment
of the requirements for the degree
of
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ACCEPTANCE

This dissertation was prepared under the direction of the candidate's Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics in the Andrew Young School of Policy Studies of Georgia State University.

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ABSTRACT

THE EFFECTS OF AIR POLLUTION ON INFANT HEALTH:
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by

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Adverse birth outcomes have many causes but there is increasing awareness that air pollution is one of them. This study examines the effects of air pollution on infant health and mortality using data from the State of Georgia. The estimation methods control for potential endogenous variables such as the length of gestation and the demand for prenatal care. Moreover dummy-fixed effects are used to control for unobserved neighborhood characteristics using the place of residence of the mother. In addition, the model uses a comprehensive framework, which considers birth weight, length of gestation, and mortality, thus allowing pre and postnatal assessment of the impact of air pollution on health. The empirical results show moderate evidence of an effect of air pollution on low birth weight and length of gestation and found a more substantive effect on infant mortality.

CHAPTER ONE: INTRODUCTION

Despite having one of the best health care systems in the world, the United States continues to have some of the highest rates of infant mortality and low birth weight among industrialized countries. The picture is worse in the state of Georgia; the infant mortality rate exceeds the national rate. In 2002, it was 8.9 per 1000 deaths compared to 7 per 1000 nationally. Similarly, the incidence of low birth weight births in the state was 9.0% compared to 7.8% for the nation, according to the Georgia Division of Public Health (2002) report.

One source of health problems in the United States is air pollution. Although government policy has been enacted to help achieve cleaner air, for example, the Clean Air Act, there are more than 146 million Americans living in counties[1] that do not meet the 1997 Clean Air Act standards for at least one of the six "criteria air pollutants,"[2] according to the Environmental Protection Agency EPA (2003). The city of Atlanta, GA was ranked 7th among the 25 most polluted all-year round cities in the United States with PM2.5[3] and was ranked 21st in ozone pollution in 2004 by the American Lung Cancer Association (2004).

Both air quality and birth outcomes are important public issues. Poor birth outcomes have substantial costs attached to them. Cultler and Meara (1999) estimated that a neonatal intensive care unit costs up to $2,200 per day for a very low birth weight baby in 1996 dollars. In addition

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[1] For the EPA's (2003) list of non-attainment counties, see Appendix A.
[2] The six pollutants are: Ozone, particulate matters, sulfur dioxide, carbon monoxide, nitrogen dioxide, and lead.
[3] PM2.5 are fine particulate matters with an aerodynamic diameter equal or less than 2.5 μ m. There are also larger particles or PM10, which have a diameter of 10 μ m or less.

they estimated that the costs involved in caring for low birth weight infants are 10 to 20 times more than the costs of a normal birth weight baby.

The direct costs associated with air pollution are the ones related to the treatment of illnesses such as asthma and other diseases. The indirect costs include loss of wages due to sickness, decrease in productivity, and school absenteeism.

The goal of this study is to examine the effects of air pollution on infant health using data for the state of Georgia. The methodological approach taken is to specify and estimate a health production function. This allows for the joint determination of both birth weight and length of gestation, as measures of infant health. The impact of air quality is estimated. We also consider whether air pollution has a measurable impact on infant mortality. Results from this research should help to inform policy makers of the relationship between air quality and infant health outcomes. These issues have only recently begun to receive attention from the Environmental Protection Agency.

The data come from the Georgia Department of Vital Statistics, the Georgia Department of Community Health and the 2000 Census of Population and Housing. The dataset comprises the birth and death certificates of all infants born in Georgia in 1997. The environmental data come from the 1997 National Emission Trend (NET) for the state of Georgia at the county level.

The dissertation is organized as follows: Chapter one discusses the motivation of this dissertation, examines the conceptual framework for this study and addresses the research questions, and offers some policy implications. Chapter two reviews the current literature on the effects of air pollution on infant health and others factors also affecting infant health. Chapter three presents the methodology, and specifies the theoretical and empirical models. Chapter four discusses the data sources and variables of interest. Chapter five goes into the analysis of the results. Chapter six addresses the contribution of this study to the current literature and concludes by giving some policy implications and limitations of this study.

Motivation

Birth outcomes

The United States faces enormous health challenges; the Healthy People 2010,[4] HHS (2006), goals established by the Federal government seek to provide a health care system that will alleviate the high rate of infant mortality, low birth weight and premature deliveries. Improvements have been made; the rate of infant death (death within one year of birth) among the total population went from 7.2 per 1,000 live births in 1998 to 6.8 per 1,000 in 2001. However, the numbers show a different picture when stratified by race; the black infant mortality rate was 13.5 per 1,000 compared to 8 per 1,000 for the non-black rate. The goal is to reach 4.5 deaths per 1,000 by 2010.

The leading causes of death among infants are congenital malformations, low birth weight (LBW), preterm births, and sudden infant death syndrome (SIDS). The racial disparities are more evident among LBW infants (weight less than 2500 grams or 5 1/2 lb) and very low birth weight babies (VLBW, weight less than 1500 grams or 3 1/4 lb). In 2001, 13 % of black infants had a LBW and 3% had a VLBW compared to 6.7% and 1.2%, respectively, for non-black infants. The national goal is to reduce the incidence of low birth weight to 5.0% for LBW and 0.9% for VLBW. According to the U.S. Department of Health and Human Services, an increase of 250 grams in birth weight saves more than $12,000 to $16,000 in first year medical

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[4] Healthy people 2010 is a federal program aimed at preventing a number of diseases affecting the nation over the first decade of the new century. It has 21 focus areas that intend to improve the quality of health services and eliminate disparities.

expenses, while prenatal care that results in a healthy baby saves more than $60,000 in medical expenses in the first year of life. The birth weight of the infant has long been considered as the most important predictor of infant survival, Institute-of-Medicine (1985). Low birth weight[5] infants are also more likely to suffer throughout their life from learning disabilities, attention disorders, and others health problems such as cerebral palsy. The acuteness of these disorders increases with the decrease in birth weight. It is important for policy makers to find ways to prevent the incidence of LBW infants, especially when it is costly to care for them.

Within Georgia there are differences in some subgroups of the population. Tables 1 and 2 display infant mortality rates and other birth outcomes by race.

Table 1: Infant Mortality and Prematurity Rates by Race

Rates (per 1000 births)	BLACK	NON-BLACK
Death within one year	15	8
Death within 28 days	12	6
Premature	186	137

Source: Georgia Department of Vital Statistics

Table 2: Birth Weight Outcomes by Race

Birth Weight Outcomes	NON-BLACK	BLACK
Variable	Mean	Mean
infant weighs less 1500g	0.0591	0.1106
infant weighs > 1500g but <2500g	0.0049	0.0153
infant weighs > 2499g	0.9361	0.8741

Source: Georgia Department of Vital Statistics

[5] LBW infants are divided in two groups; one being premature babies and the other one is defined as infants who suffer from: intrauterine growth retardation. The second condition is very difficult to measure in our data as it is based on morphologic information, such as length and head circumference, that are not available.

Many existing government policies are aimed at reducing infant mortality and improving infant health. For example, the “Right from the Start Medicaid” program covers medical expenses for pregnant women and their children for up to one year. These services include post-partum home visits, substance abuse treatment, education literature, and medical care. In addition, the Department of Agriculture offers a supplemental nutrition program for women, infants and children, commonly known as WIC. This program gives foods, such as infant formula, cereals, vegetables, and juices and it also provides counseling to low-income women and their children at no charge.

The health of infants and their mother’s is an important health indicator of the current health system, and the nation, in general. The State of Georgia continues to have high rates of infant mortality and morbidity and continuous health disparities among different races relative to the rest of the nation.

Air pollution

Despite many toxicological and epidemiological studies that examine the characteristics of the effects of air pollutants, the mechanism underlying the effects of air pollution on health is not fully understood. Children and infants seem to be more at risk than adults mainly because of physical characteristics. Moreover, it is expected that the effects of air pollution on adults are more gradual than the more direct effects on infants. There is increasing awareness that air pollution is more detrimental to infant health than to adults. Succinctly, infants are more susceptible to the adverse effects of air pollution because their immune system and vital organs are still immature, for example, inflammations caused by air pollution are more likely to obstruct their small airways compared to adults. In addition it takes smaller levels of pollutants to trigger an asthma attack or cause some other form of respiratory distress relative to an adult.

Recent evidence by Illig and Haldeos (2004) from the World Health Organization showed that the exposure of pregnant women to air pollution could hinder the development of the respiratory, the nervous, and the immune systems of the fetus. Perera, Jedrychowski, Rauh, and Whyatt (1999) concluded that the vulnerability of fetuses and infants to PM10 is due to their lack of strength relative to adults. In addition, the fetal process is very sensitive to any adverse environmental toxins because it is a process where highly specialized cells are undergoing growth or differentiation. During this time period, their metabolic system is less able to detoxify toxins than adults. Schwartz (2004) tells us that lungs are not well formed at birth and that the full development occurs after age 4; the number of alveoli in the human lung increases from 24 million at birth to 257 million at age 4. Furthermore, Pereira, Loomis, Conceicao, Braga, and Arcas (1998) using data from Sao Paulo, Brazil, found that carbon monoxide interfered with the oxygen level of fetuses through the creation of carboxyhemoglobin. Nitrogen dioxide was found to increase the level of methemoglobin, which is known to interfere with the oxygen carrying capacity of hemoglobin.

The descriptive maps of the state of Georgia for carbon monoxide and fine particulate matters clearly show spatial patterns especially near urban areas. Both pollutants tend to be concentrated near the Atlanta region and the Southeast corner of the state, see maps 1 and 2.

According to the Georgia Conservancy (2003) the city of Atlanta ranked fourth nationally in transportation related public health costs in 2003. The report notes that the number of unhealthy days increased by 17%, which correspond to 76 unhealthy days[6] between 2000 and 2002.

Conceptual Framework

There are two basic research questions. First, what are the effects of air pollution on infant mortality? Secondly, does air pollution increase the incidence of low birth weight and preterm deliveries? We provide a theoretical framework for considering these questions. The model is based on the household production function which has been widely used in the economic literature: (Rosenzweig and Schultz 1983; Joyce 1986; Warner 1995). The household production function assumes that infant health is an argument in the parent's utility function and that the parents are constrained by income and time.

The theoretical model informs the specification of the empirical model. One difficulty is the precise measurement of air quality. As the maps indicate, air pollution is more concentrated in some areas than in others. However the monitoring system that measures concentrations of pollutants might not fully capture variations across neighborhoods. Therefore, We enrich the measure of neighborhood air pollution by incorporating neighborhood fixed effects, as in Currie and Neidell (2004).

[6] The Air Quality Index (AQI) reports the daily quality of the air throughout the United States. It varies from 0 to 500. A higher number represents unhealthy air quality. When the values of the AQI reach between 151 to 200 then it is considered to be unhealthy for everyone

Public Policy Implications

A variety of public health issues are addressed in this study. This study provides evidence on the effects of different air pollutants such as particulate matters (PM10, PM25), carbon monoxide (CO), sulfates (SO2) and nitrates (NOX) on infant health. This evidence can inform public policy regarding the effectiveness of air quality standards. In addition, this study will provide some insight into the utilization of Medicaid insurance coverage by low-income women. Finally, this study will provide evidence on the importance of the place of residence on birth outcomes.

CHAPTER TWO: LITERATURE REVIEW

Air Pollution Effects

Several studies have found that exposure to sulfur dioxide (SO2) and particulate matter (PM10, PM25) increased the probability of infants born prematurely, and with a low birth weight (Krewski, Burnett, and Goldberg 2000; Liu, Kreswki, Shi, Shen, and Burnett 2003; Maisonet, Correa, Misra, and Jaakkola 2004; Pope 2000; Ritz, Fei, Guadalupe, and Scott 2000; Schwartz, Slater, Larson, Pierson, and Koenig 1993; Wang, Ding, Ryan, and Xu 1997; Wilhelm and Ritz 2003). Studies conducted in Eastern Europe also found a significant relation between adverse health outcomes and air pollution. The Teplice study in the Czech Republic found that infants run a higher risk of intrauterine growth retardation (IUGR) when their pregnant mothers were exposed to high level of PM10, and they found a positive relationship between particulate matters and post neonatal infant mortality after controlling for socio-demographic factors (Dejmek, Selevan, Benes, Solanski, and Sram 1999; Zidek, Wong, Lee, and Burnett 1996).

Currie and Neidell (2004) examined the effects of air pollution on infant health using California data from 1989 to 2000. The authors estimated two probability functions, one estimating the prenatal effects of air pollution on infant health and the second estimating the post-natal effects on infant mortality. They recognized that air pollution could be correlated with poor infant outcomes through unobserved characteristics that are correlated with both infant health and air pollution, such as the quality of drinking water. They used a zip code fixed-effects model to account for that correlation and found that PM10 and CO have adverse effects on infant mortality. However, the effects of air pollution on gestation disappeared after controlling for these neighborhoods fixed effects. The study concludes that the diminution of air pollutants in the 1990's in the state of California saved more than a thousand lives.

The effects of confounders have also been addressed by Chay and Greenstone (2003) which used the Clean Air Act of 1970 and the following 1980 recession as a "quasi-natural experiments" to explore the policy effects on infant deaths. Their study found a positive and significant link between pollution and infant deaths but no effects on low birth weight.

Chay and Greenstone's study found that 25,000 more infants survived to one year of age due to the air quality improvement after the 1980 recession. In addition, the study shows that a decline of one microgram per cubic meter in TSP resulted in five more infants surviving for every 100,000, and that, counties with the highest drop in TSP (total suspended particles) levels also had the biggest decrease in infant mortality. However, their study used TSP as a measure of particulate matter, and TSP has been criticized as being too large relative to PM2.5 which is more likely to be small enough to enter deep into the lungs (thoracic particles). In fact, the evidence found on the effects of PM2.5 on infant health led to the revision of the PM2.5 standards of the Clean Air Act in 1997 and 2002.[7]

Moreover, particulate matters have been associated with increased cardiopulmonary and respiratory hospitalization, mortality and lung cancer in adult and infant populations: (Dockery 2001; Environmental Protection Agency 2001; Gauderman, McConnell, and Gilliland 2000; Pope, Burnett, and Thun 2002). These studies found that for every 10 $\mu g/m^3$ increase in particulate air pollution lead to an average increase in daily mortality rate between 0.5% and 1.6%. More importantly, these results were even found in cities with a typical concentration of

[7] The Clean Air Act requires the Environmental Protection Agency (EPA) to review and update the National Air Standards for the criteria pollutants every five years in light of new evidence.

air pollution. In addition, Lipsett, Hurley, and Bart (1993) found a significant link between air pollution and emergency visits for asthma.

Long-term epidemiological studies also showed a link between particulate matters and others pollutants on infant mortality. Two main studies were Dockery, CA, and Xu (1995) and Pope, Thun, Nambodiri, Dockery, Evans, and Speizer (1995). The first study found that an increase in fine particulate matters and sulfates were associated with a 26% increase in mortality for all causes of death when comparing the least polluted to the most polluted city. Moreover, the authors found that fine particulate matters were linked to cardiopulmonary disease. Their analysis was a prospective cohort study, which followed 8, 111 adults from six U.S. cities. They used particulate matters, sulfates, ozone and sulfur dioxide and they controlled for age, smoking, occupation and medical history. The authors computed city-specific mortality rate ratios adjusted for various health risks to rank the different cities. Indeed, increase mortality was strongly associated with PM2.5 and fine sulfate particles relative to total suspended particles or TSP. In addition, fine particles are able to go indoors resulting in strong correlation between outdoor and indoor levels of pollution thus making them good estimators of air pollution exposure, according to the authors.

Pope et al. (1995) used a larger sample to evaluate the effects of sulfate and fine particulate matters on mortality. They used a sample of over 500, 000 adults from 151 U.S. metropolitan areas. The authors used adjusted mortality ratios controlling for age, smoking, and medical history and others cofounders. Again, fine particles were strongly linked to cardiopulmonary disease and to all causes of death among smokers and non- smokers. The authors found a 15 to 17 % difference in the least to the most polluted cities between fine particles and increasing mortality. The study also found that their results were robust to the exclusion of confounders such as occupation, alcohol consumption, and weather.

Those two studies were particularly important, as they were the basis for the revision of the Clean Air Act in 1997, by the EPA, and the Health Effects Institute study with Krewski, Burnett, and Goldberg (2000). Their results were scrutinized and thoroughly reanalyzed by a team of experts from the HEI in 2000 that used the same data and statistical methods to replicate those studies. The team led by Dr Krewski found similar results even when they applied spatial techniques to account for potential spillovers. While the effects of some pollutants were diminished, nevertheless, there were still a significant link between air pollution and increased mortality.

Carbon monoxide, particulate matters and nitrogen dioxide are closely related to traffic related pollution: (Delphino 2002; Keonig, Jansen, Allen, Lumley, and Mar 2005; Oyana and Lwebuga-Mukasa 2004; Perlin, Sexton, and Wong 1999; Wilhelm and Ritz 2003) are among a new trend of epidemiological studies that are focusing on the location of residence and the proximity to high traffic areas and industrial sites on infant health. These studies found that there is an increase risk of adverse health effects for populations living near high traffic areas such as highways and high-traffic roads. Moreover, Delphino (2002) also showed that there is an increase risk of respiratory diseases such as asthma and wheezing, and children's cancers to proximity to high traffic locations.

Neighborhood Effects

A critical issue in both the theoretical and empirical models of household behavior that are specified here is the importance of residential location in affecting the health of both mother and child. I postulate that the location decision of the household is correlated with unobservable variables that in part determine household health. For instance, low-income households are more likely to reside in central cities due to segregation and other urban-specific factors that confine them in areas of high poverty and unemployment. This is commonly referred as the spatial mismatch hypothesis in the urban literature, Sjoquist and Ilanfeldt (1989).In terms of health effects, this spatial mismatch could result in less access to health providers or to high quality health care. There is increasing evidence that neighborhood matters (Case and Katz 1991; Cohen, Mason, Bedimo, Scribner, Basolo, and Farley 2003; Cutler and Glaeser 1997; Hockman and Morris 1998; Mathesson, Burr, and Marshall 1998; Oakes 2004). All showed that the existence of localized contextual effects could affect health, employment, and educational outcomes of populations living in disadvantaged neighborhoods. In others words, households residing in different neighborhoods have different health outcomes, as certain areas offer a safer environment, and better air and drinking water quality relative to high density, urban places, for instance. In addition, neighborhood effects also have an impact on disease clustering (spatial variation in mortality) in terms of cultural norms, disease transmission, housing and environmental conditions.

Cohen et al. (2003) investigated the effects of neighborhood conditions (boarded houses) on the transmission rate of gonorrhea and premature death. They found the condition of the neighborhood is a good predictor of gonorrhea rates and premature mortality. There are several ways the place of residence could affect infant health, including local government spending on health care or the presence of hazardous sites. The health districts in the state of Georgia show important differences in terms of the supply of medical services, such as, the number of pediatricians or the number of doctors accepting Medicaid recipients.

A studies done by the Georgia Division of Public Health (1995; Georgia Division of Public Health 1997) showed that some health districts are faced with acute staffing problems, especially nurses who are supposed to conduct home visits for high-risk mothers in prenatal case management programs. In addition , a study by the U.S. general accounting office in 1987, (U.S. 1987) showed that low- income women have definite problems of access to prenatal care, and one of the most important factors cited was the supply of doctors in certain urban centers and rural areas.

Mathesson et al. (1985) used the logistic model with random effects to examine the effects of individual and neighborhood factors on infant mortality at the county level. They found that the level of poverty increases the probability of infant death, but they also acknowledged that poverty rates are highly correlated with high crime rates, poor housing conditions, negative educational outcomes and exposure to hazardous pollutants. Surprisingly, they found that the number of physicians and hospitals, and health expenditures increased the probability of infant death therefore hinting at potential problems in their study.

The Role of Prenatal Care

The link between prenatal care and infant health is very challenging due to the correlation between the mother's health endowment and attitude toward the pregnancy, which are largely unobserved, and the consumption of prenatal care.

From a public policy perspective, prenatal care is one of the most important preventive programs against low birth weight and prematurity, Institute-of-Medicine (1985). Interestingly, as Dubai, Joyce, Kaestner, and Kenney (2001) showed the results of studies on the effectiveness of prenatal care are mixed. Their study found that access to expanded Medicaid benefits and prenatal care to low-income women did not improve their birth outcomes.

Liu (1998) estimated four birth weight production functions that are differentiated by race and geographic location. The results of his study show that the women's self-selection will undermine the returns of prenatal care services on pregnant women; in addition he found large differences in the effectiveness of prenatal care utilization across different groups of women.

Joyce (1986),and Warner (1995; Warner 1998) assumed the endogeneity of prenatal care, and used a two-stage least squares regression to control for unobserved selection. The authors found that ordinary least squares underestimate the effects of prenatal care thus pointing to adverse selection in the demand of care.

The quality of prenatal care has been widely ignored by previous research on infant health; however there are a number of studies that examined the quality of health care utilization: For example, Buescher and Ward (2001) examined the differences between public care and private care, and concluded that low income women receiving care in a public hospital have better birth outcomes than women who receive care in a private practice located in a low income neighborhood. This is largely because public facilities provide a more comprehensive care to pregnant women.

Khoury, Weisman, and Jarjoura (1993) studied ownership type and women's health centers. They found that non-profit community health centers provided a broader range of services for low-income patients relative to for-profit centers. Moreover, waiting time, scheduling difficulties, failure to provide adequate information, and lack of continuity are all cited as major sources of problems for women receiving prenatal care.

To eliminate the financial barriers to prenatal care, Medicaid insurance is provided to low-income pregnant women. However Medicaid does not ensure that they will receive the highest quality of prenatal care compare to pregnant women with private insurance. The effect of Medicaid programs on birth outcomes has been widely investigated (Currie and Cole 1993; Currie and Gruber 2001).

Currie and Cole (1995) looked at the links between AFDC receipts and birth weight. Their initial estimation using OLS found that the participation in AFDC would result in lower birth weight. However, they found that AFDC has a positive effect on mother's birth outcomes if unobserved factors are controlled, by using either a two-stage least squares or a fixed effect model. This suggests that there is self-selection in the Medicaid population. The participation to those programs is strongly related to negative behaviors such as illegal drug and alcohol use, and smoking. Thus participation in these programs such as Medicaid or Head Start is not random hence raising the possibility of endogenous covariates. Moreover, there are still other barriers to health care such as structural barriers which include the availability of health care centers and transportation accessibility; cognitive barriers including the patient's knowledge and expectations, and socio-demographic barriers that include the patient's age, marital status and race, according to Margolis, Carey, Lannon, Earp, and Leininger (2003).

To summarize these findings: The majority of the studies report a positive link between air pollution and mortality: (Chay and Greenstone 2003; Currie and Matthew 2004; Dejmek et al. 1999; Dockery, C Arden, and Xu 1993; Pope et al. 1995; Zidek et al. 1996) despite the differences in terms of time periods, measurements and number of pollutants, and strength of association. There was more evidence that air pollution affects post-neonatal mortality than neonatal mortality: (Chay and Greenstone 2003; Lave and Seskin 1973). Time series studies in general had difficulties in controlling for potential confounders such as smoking, and exposure to all pollutants. Moreover, the omission of neighborhood fixed effects, indoor pollution and occupation will likely bias the measurement of the level of exposure. Finally, there are unclear evidence on the effectiveness of prenatal care and expanded governmental benefits to low-income women.

CHAPTER THREE: METHODOLOGY

The health production function model reflects the technological and biological processes that affect the behavior of households in their production activities: (Joyce 1994; Rosenzweig and Schultz 1983; Warner 1995, 1998). This model evaluates how economic and biological constraints alter the behavior of households, which in return affects the health of the infant. The model allows for households to differ in their health endowment hence their demand for inputs will also be different. The mother's utility function is of the following form:

(1) $\text{Max } U(H, \Pi, X)$

where H is her infant's health at birth, Π is her probability of infant's survival, and X is a composite good including leisure. The mother maximizes her utility function subject to the infant health production function, and her budget constraint, which are respectively

(2) $H = H(Pnc, Z)$

where Pnc is prenatal care and Z is a vector of other variables affecting child health.

(3) $Y = P{*}Pnc + X + R$

with Y denoting income, P defined as the price of a unit of prenatal care, and R defined as the dollar expenditure on housing. The price of X is normalized to 1.

It is expected that the mother will choose the optimal level of prenatal care. Pnc should have a positive impact on infant health. The vector Z contains other variables known to directly affect infant health, such as socio-demographic characteristics (age, education, marital status, and insurance coverage), neighborhood factors (per capita income, percent black and female head of household, air pollution, and number of doctors), and maternal behaviors, such as smoking and drinking during pregnancy and health status of the mother at the time of delivery.

The maximization of equation 1 subject to 2 and 3 leads to structural equations of the following form:

(4) $H^{*} = H(Pnc^{*}, Z, \epsilon_{h})$ and

(5) $Pnc^{*} = Pnc(P, Y, Z, \epsilon_{Pnc})$

where stochastic terms have been incorporated. The mother cares about the survival of her infant, thus the maximization also yields an equation for the probability of her infant surviving his or her first year

(6) $1- \Pi^{*} = \Pi(H^{*}, Z, E, \epsilon_{\Pi})$

with E represents environmental factors.

The stochastic term, the ϵs capture unobservable family-specific characteristics, which are presumably known to the families, they include biological and genetical endowment. These terms are also a source of individual heterogeneity, which will be addressed in the empirical specification.

Empirical Estimation

There are a number of econometric challenges in the estimation of infant health production function. These arise from the presence of several endogenous inputs and the joint determination of such outcomes as gestation length and birth weight. Furthermore, gestation length and birth weight are both inputs for the infant mortality equation. Thus, the estimation strategy relies primarily on instrumental variable (IV) methods.

Separate regressions by race are used to avoid possible correlations between race and input demand. It is common practice in the literature to stratify by race to achieve better homogeneity in the sample.

Estimation is carried out using two different specifications: an IV model and a model that incorporates fixed effects by Pumas. A Puma is an area that defines a space by which the Census Bureau tabulates the public use micro data sample (PUMS) data. It is expected that the fixed effects model will yield better results than the pooled specification as it allows the different intercepts to account for time-invariant unobserved location effects. For example, it is possible that employment and health outcomes are correlated to unobserved neighborhood characteristics, due to the sorting of households across jurisdictions. The neighborhood dummy variables would capture these unobserved effects. To the extent that these neighborhood effects matter, we would anticipate that the IV estimates would suffer from omitted variable bias.

The prenatal care equation

R&S hypothesized that a woman's demand for prenatal care is strongly related to her health status, therefore if she has a chronic disease, she is more likely to use more prenatal care compared to someone without any chronic ailment. This implies that pregnant women should be split into two groups: low and high demanders of services. One simple way to possibly capture this effect is to measure prenatal care by using the number of prenatal care visits along with the number of visits squared. There are a number of pregnant women that receive a very large number of prenatal visits due to pregnancy complications. In order, to account for potential non-linearities effects, both the number of visits and its square are regressed on the same set of exogenous variables.

The mother and her doctor know the mother's health status but it is only partially observed to the researcher. Thus the influence of the health endowment comes partially through the equations' disturbance terms. Because the health endowment affects the birth weight, the length of gestation and the demand of prenatal care, the correlation between the random disturbances and these variables mean that instrumental variable (IV) methods must be used to allow consistent estimation.

The equation for prenatal care utilization is given by equation

(7) $$Pnc_i = b_0 + b_1X_i + b_2\, S_j + b_3\, N_j + \epsilon_{Pnc}$$

Equation 7 shows prenatal care as a function of socioeconomic characteristics, Medicaid insurance, and neighborhood factors. Both, the supply of doctors at the county level and a crime index are considered as instruments.

In this study, we have chosen to use the number of prenatal visits received by the pregnant mother as a measure of prenatal care utilization. This is commonly available from the birth certificate. As mentioned above, the number of visits squared is also included to account the nonlinearity. The majority of studies in the medical field use single equation models to investigate the effects of prenatal care utilization on infant health, and many of them agree that it is appropriate to use prenatal care indices such as the Kotelchuck index of adequacy of receipt of prenatal care, Kotelchuck (1994) or the Kessner index, Kessner, Schlesinger, Kalk, and Singer (1973). These indices control for several characteristics affecting the utilization of prenatal care such as the timing or delay factor, the number of visits, and any adjustment to the length of gestation. However, the estimation becomes problematic when ordinal measures such as indices are treated as endogenous.

Smoking and participation in public programs such as AFDC, Medicaid or WIC are treated as exogenous due to the lack of valid instruments. For instance, smoking during pregnancy could be correlated to the availability of smoking cessation programs in prenatal care services.

The length of gestation equation

The process that underlies the length of gestation is very unclear; half of all women that have a premature infant do so for no known reasons, according to a Mayo-Clinic (2004) report. The report continues by pointing to some potential reasons for prematurity such as high blood pressure, diabetes, an abnormal shape of the uterus, and a previous premature delivery. In addition, a shortened cervix and pre-eclampsia are warning signs for a premature birth. Both conditions require the delivery of the baby as the only recourse to save the life of both the mother and the baby.

The estimated production function is of the following form:

(8) $$G_i = b_0 + b_1 X_i + b_2 M_i + b_3 N_j + \epsilon_g$$

where the dependent variable is the length of gestation in weeks[8].

X_i is a vector of socio-economic characteristics and M_i includes hypertension, bleeding, eclempsia, incompetent cervix, premature rupture, abruptio placenta and placenta previa (see Appendix B for a medical term dictionary).Birth risks that are known to be related to premature conditions but not birth weight, such as eclampsia, hypertension, bleeding and others labor risks, which are used to identify the length of gestation function. N_js are neighborhood characteristics at the county level.

[8] In this study, both birth weight and length of gestation are considered as outputs in the health production function.

The birth weight equation

The household health production function is of the following form:

(9) $Wi = b_0 + b_1 X_i + b_2 N_j + b_3 R_i + \epsilon_w$

The coefficients measure the responsiveness of weight to biological and economic constraints. The dependent variable is the birth weight of the baby in grams.

The specification assumes a linear functional form for equation (9) to assess the direct impact of air pollution on birth weight and gestational age[9] with two-stage least squares. The estimation requires a set of instruments, which need to be correlated to the length of gestation or prenatal care but not to the birth weight of the baby.

The birth weight production function is identified by the birth risks weight gain, and parity, that are contained in the vector R, and neighborhood level variables in N such as pollution, income, percentage black, and percentage of female head of household with children less than 18 year.

Infant mortality equation

The dependent variable is a dichotomous variable that takes the value of one if the infant died within one year, and zero otherwise. Thus equation 10 estimates the probability of survival for one year from the time of birth conditional on a live birth.

(10) $1\text{-}\Pi = \Pi \{Xi, H_i, E_j, \varepsilon_\Pi)$

[9] This model is also complicated by the existence of several potential birth outcomes such as fetal death, abortion, miscarriages, and intra uterine growth retardation (IUGR). Unfortunately, this study will not control for abortion, fetal death, and IUGR due to data limitations.

1-∏ corresponds to the probability of death within one year.

H_i are health characteristics of the mother and her infant.[10]

E_j corresponds to area characteristics including the level of pollution in county j.

X_is and $H_{i's}$ are demographic and health characteristics, such as, birth weight, age, education, income, marital status, birth and labor risks such as the Apgar score, and abnormal and congenital conditions at birth of baby. The presence of "father's name" on the birth certificate, and unemployment rate are included in the prenatal care and infant mortality equations but not in the birth weight production functions.

Air pollution effects are expected to be detrimental to all birth outcomes, but we hypothesize that they will be stronger in the infant mortality. Moreover, the presence of harmful neighborhood and peer effects could also be detrimental to the health of both mother and infant. Localized geographical externalities are captured by the place of residency (urban or rural), whether the county is a non-attainment county, and hospital characteristics, such as the type of ownership. Furthermore, the level of pollution is expected to be higher in urban areas than in non-urban areas, thus an interaction term using the particulate matter levels and the residence of the mother was created to capture the effects of urban pollution on birth outcomes.

The effects of maternal education and age on birth outcomes have been widely examined in health studies. It is expected that more educated women will have better birth outcomes because there will be more efficient in producing healthier babies by having healthy behaviors such as exercise and proper nutrition. Furthermore, maternal age behaves in a non-linearly manner as younger and older women have been known to suffer from adverse birth outcomes. Nevertheless, as individuals age their health endowment deteriorates.

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[10] The effects of the length of gestation and prenatal care on infant mortality are through the birth weight.

The effects of marital status have been known to positively impact health outcomes, as it is a proxy for pregnancy wantedness and spousal support. On the contrary, having no father's name on the birth certificate is expected to negatively impact health outcomes and the demand for prenatal care, even though it neglects the role of the extended family.

Several variables, such as per capita income, percentage of black households, percentage female heads of households, and percentage of households on public assistance capture the effects of income and poverty. Income is expected to have a positive effect on birth outcomes and the demand for care while poverty characteristics are projected to negatively impact birth outcomes.

All the birth and labor risks, such as smoking, drinking, and health risks affecting the mother and the infant are expected to be detrimental to their health even though diabetes has been known to increase birth weight to the extent of being linked to child obesity.

It is important to note that the incidence of some diseases vary by race. Diseases such as hypertension and diabetes are very predominant among African-Americans, and it has been shown in the health literature that diabetes is complicated by others illnesses such as hypertension. In addition, the long-term consequences of hypertension could lead to cardiovascular and renal ailments. Hence, an interaction term containing chronic hypertension and diabetes have been created to better capture its effects on birth weight and length of gestation.

Medicaid insurance and the supply of health services have been recognized to lower the costs of the utilization of medical services thus there are expected to positively impact birth outcomes and the demand for care. To better assess the impact of government intervention in low-income neighborhoods, an interaction term was created between Medicaid insurance coverage and zip codes with the percentage of female head of household.

CHAPTER FOUR: DATA SOURCES

The birth record is from the Georgia Department of Vital Statistics (Georgia Department of Medical Assistance). It comprises the birth and death certificates of all infants born in Georgia in 1997. The Georgia County Guide, the Georgia Department of Community Affairs and the 2000 Census of Population and Housing were used to get county and zip code level data, which were merged using the address of the mother. In addition, the 2000 Public Use Microdata, 5% sample was used to identify the neighborhood fixed effects. Tables 3, 4 and 5 have the descriptive statistics for the variables used in the estimations.

The sample is composed of 30,738 observations of black mothers and 65,932 of non-black mothers who gave birth in Georgia in 1997. It is restricted to infants with a birth weight of 300 grams and having 21 weeks length of gestation or more, as they could be measurement errors or not viable infants. Moreover, teenage mothers were excluded due to the endogeneity of some choice behaviors including marriage or dropping out of school at the time of the pregnancy.

Table 3 reveals that non-black infants weigh, on average, 255 grams more than black infants and have a longer length of gestation, 39 weeks relative to 38 weeks for black infants. More than 1% of black infants in our sample died before their first birthday, compared to 0.007% for the non-black sample. Moreover, 6% of non-black infants were either low birth weight or very low birth weight compared to 12% in the black sample (see chart 1).

Table 3: Birth Outcomes and Demographic Means

Variable Means	**Black**				**Non-black**			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Birth outcomes	**N=30738**				**N=65932**			
Birth weight (grams)	**3122.2510**	651.4314	312	5840	**3377.4410**	588.4423	312	6379
death within one year	**0.0147**	0.1205	0	1	**0.0076**	0.0868	0	1
Death within 28 days	**0.0116**	0.1070	0	1	**0.0057**	0.0753	0	1
Length of gestation (weeks)	38.5055	2.6914	21	44	38.9872	1.9884	21	44
premature (28 to 37 weeks)	0.1855	0.3887	0	1	0.1368	0.3436	0	1
Demographic								
Prenatal visits	11.4564	4.2036	0	49	12.4719	3.8630	0	49
Weight gained	28.9284	13.8238	0	98	30.9378	12.0631	0	98
parity	1.2328	1.3399	0	15	0.9144	1.0468	0	15
urban residence	**0.8026**	0.3981	0	1	**0.5142**	0.4998	0	1
young woman	**0.4985**	0.5000	0	1	0.3361	0.4724	0	1
woman	0.4144	0.4926	0	1	0.5561	0.4968	0	1
old woman	0.0871	0.2820	0	1	0.1078	0.3101	0	1
less high school degree	0.1733	0.3785	0	1	0.1672	0.3731	0	1
high school degree	0.4177	0.4932	0	1	0.3174	0.4655	0	1
some college	0.4004	0.4900	0	1	0.5025	0.5000	0	1
married	**0.3672**	0.4821	0	1	**0.8360**	0.3703	0	1
father's name not present	**0.3316**	0.4708	0	1	**0.0743**	0.2623	0	1
female (gender of baby)	0.4883	0.4999	0	1	0.4891	0.4999	0	1
Medicaid	**0.5757**	0.4942	0	1	**0.2960**	0.4565	0	1
smoke	0.0539	0.2258	0	1	0.1154	0.3195	0	1
drink	0.0108	0.1034	0	1	0.0078	0.0882	0	1

The average age of a non-black mother was 28 years old, while the average black mother was 26. One striking feature in the sample is the percentage married, 84% of non-black mothers were married while 37% of black mothers were married at the time of birth.

Chart 1 provides some cross-tabulation of the data, where the mothers are partitioned into age categories. It shows that the largest difference in birth weight between black and non-black mothers is in the older group (average age is 38 years), non-black infants are 281 grams heavier compared to black infants. The lowest difference is in the young group (average age is 22 years), where non-black infants are 231 grams heavier. Moreover, the highest risk group is the old group in the black sample, which has the highest incidence of infant mortality, and low birth weight.

There are still more racial differences in terms of prenatal care consumption; 90% of non-black mothers started their doctor's visits in the first trimester of their pregnancy compared to only 80% of black mothers. There are twice as many black mothers that received no prenatal care during their pregnancy than non-black mothers. Among the very low birth weight infants, 5% of their mothers did not receive any prenatal care during their pregnancy; see chart 2.

As Table 3 shows, black mothers smoked less and had more medical and labor risks than white mothers during their pregnancy. The data shows that 57% of black mothers and 29% of non-black mothers received Medicaid coverage during their pregnancy. In addition, Medicaid infants are twice as likely to die within one year relative to non-Medicaid infants, see chart 3.

The environmental data are from the 1997 National Emission Trend (NET) for the state of Georgia by county. The data only includes information on area source pollutants, which are related to emissions from cars, trucks and non-road engines. From this data, only these criteria pollutants are selected: particulate matter (< than 10 micrometers) (PM10), particulate matter (<

than 2.5 micrometers) (PM2.5), sulfur dioxide (SO2), carbon monoxide (CO), and nitrogen dioxide (NO2). The units are in short tons which correspond to 2, 000 pounds of emissions.

Particulate matters or (PM) are particles such as dust, dirt, smoke, and droplets found in the air. PM could be large (10 micrometers or microns) or they could be thoracic particles, which means that they are small enough (2.5 microns) to enter human lungs and cause severe respiratory illnesses to vulnerable population groups such as infants and elderly. They come from a variety of sources such as cars, factories, and construction facilities. The long-term exposure to PM has been linked to increased hospital admissions for people with lung or heart diseases, and to premature death. Table 4 shows that the average PM10 levels are 22, 499 short tons in black areas and 21, 508 in non-black areas.

Carbon Monoxide (CO) is an odorless and colorless gas that is emitted when fuels are not completely burned. High levels of CO are more prevalent in urban centers due to the high level of traffic and the presence of an extensive highway network. According to the EPA, 56% of nationwide CO emissions come from car exhausts. Inversion phenomena, which consist of air trapped under a layer of warm air, is more frequent during the winter thus the highest levels of CO occur during the cold season. It is also known to affect the central nervous system and can cause lung and heart diseases, and death at high levels. Finally, CO is a major contributor to ozone levels, which has been linked to various respiratory illnesses. Table 4 reveals that the mean CO in black neighborhood is 181,816 short tons while the mean in non-black areas is 17,203 lower.

Nitrogen Oxides (NOx) are formed from nitrogen and oxygen and are very reactive in the air with others gases. Most of them are odorless and colorless gases but nitrogen dioxide or NO_2, has a red-brown color. The primary sources of NOx are electrical companies and cars. Moreover, it is an important contributor to ozone and acid rain. According to the EPA, NOx is the only gas of all "criteria" pollutants that has increased since 1970. NOx has been linked to premature death and lung damage. As with previous pollutants, the levels of NOX in black areas compared to non-blacks are 2,578 short tons higher.

Sulfur dioxide (SO_2) is a gas soluble in water that reacts with others gases and particles in the air to be very detrimental to human health. It directly affects the moist surfaces of the mouth, pharynx, and bronchi. Electric utilities, refineries, cement and metal manufacturers that use coal are the major sources of SO_2 emissions. High levels of SO_2 over a short term are a major health concern for people suffering with asthma and others sensitive groups as SO_2 adversely affect the respiratory system. The average SO2 levels are 2,296 short tons in black neighborhood while they are only 2,079 short tons in non-black areas.

These air pollutants share common characteristics, as they can travel long distances, and can affect vegetation, ecosystems, and buildings. In addition, they also show very large variations across the State.

Table 4 shows the average for the six criteria pollutants used in this study for Georgia counties. The levels of all the pollutants are higher in black areas relative to non-black neighborhoods, which is consistent with environmental justice arguments. Chart 5 shows a selected number of counties with various levels of pollution; in summary, the largest counties have the highest levels of air pollution. The season of birth was included to account for any seasonal effects.

Table 4: Neighborhood Means

Variable Means	**Black**			**Non-black**		
	Mean	Min	Max	Mean	Min	Max
Neighborhood						
persons per doctor	403.3781	172.21	2182.78	509.0834	172.21	2050.71
Non-attainment counties	0.4891	0	1	0.5288	0	1
population density	956.9079	22.32	2224.64	893.6220	22.32	2224.64
percent female head household	0.1244	0	0.2727	0.0717	0	1
percent black in zip code	**0.5222**	0	0.9907	**0.1978**	0	1
percent on public assistance	0.0456	0	0.2088	0.0241	0	0.2645
percent beds in county	99.4801	0.6581	44142.86	87.8362	0.6581	54626.5100
per capita income	17832.9200	1490	85883	22384.6000	1490	85883
unemployment rate	**7.8064**	1.5	25.21	**2.6299**	1.76	9.5
crime index in county	8.1256	0.0403	11.5739	6.9712	0.0403	11.5739
Pollutants and season of birth						
warm season	0.5022	0	1	0.5069	0	1
cool season	0.4978	0	1	0.4931	0	1
pm10	**22499.5200**	2528.03	41432.71	**21508.9400**	2380.14	41432.71
pm25	**5987.4960**	617.21	11001.06	**5623.8080**	529.85	11001.06
co	**181816.2000**	7548.32	360935.9	**164613.2000**	4557.21	360935.9
nox	**27071.5200**	811.25	57088.47	**24493.3800**	746.53	57088.47
so2	**2296.0350**	49.78	4992.3	**2079.7250**	48.01	4992.3

The 2000 Census of Population and Housing provides important neighborhood characteristics such as the percentage of female heads of households and household income at the zip code level. Table 4 reveals that non-black households in general lived in neighborhoods with a low percentage of black households and female heads of household; the percentage of black household is 19% for non-black and 52% for blacks in the zip code, and 7% for non-blacks and 12% for blacks for the percentage of female heads of household.

Table 5: Birth and Labor Risks and Hospital Characteristics Means

Variable Means	**Black**				**Non-black**			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Birth and labor risks								
Heart	0.0015	0.0391	0	1	0.0028	0.0532	0	1
Lungs	0.0021	0.0456	0	1	0.0020	0.0447	0	1
Diabetes	**0.0205**	0.1417	0	1	**0.0197**	0.1388	0	1
Hydramnios	0.0082	0.0900	0	1	0.0069	0.0827	0	1
Chronic Hypertension	**0.0102**	0.1007	0	1	**0.0050**	0.0703	0	1
Hypertension	0.0253	0.1571	0	1	0.0284	0.1661	0	1
Eclempsia	0.0036	0.0597	0	1	0.0043	0.0657	0	1
Incompetent cervix	0.0036	0.0600	0	1	0.0023	0.0478	0	1
Extra bleeding	0.0014	0.0374	0	1	0.0023	0.0481	0	1
Premature rupture	**0.0275**	0.1634	0	1	**0.0222**	0.1474	0	1
Abruptio placenta	0.0058	0.0761	0	1	0.0038	0.0612	0	1
Placenta previa	0.0024	0.0487	0	1	0.0033	0.0570	0	1
others extra bleeding	0.0033	0.0572	0	1	0.0047	0.0681	0	1
Previous miscarriages	0.1747	0.3797	0	1	0.1834	0.3870	0	1
Previous abortions	**0.1102**	0.3132	0	1	**0.0698**	0.2548	0	1
congenital conditions	**0.0101**	0.0998	0	1	**0.0099**	0.0993	0	1
Abnormal conditions	**0.0454**	0.2083	0	1	**0.0393**	0.1944	0	1
bad apgar score	**0.0060**	0.0773	0	1	**0.0026**	0.0513	0	1
moderate apgar score	**0.0303**	0.1715	0	1	**0.0175**	0.1311	0	1
Hospital Characteristics								
profit hospital	0.1107	0.3137	0	1	0.1230	0.3285	0	1
public hospital	0.6960	0.4600	0	1	0.7220	0.4480	0	1
not for profit hospital	0.1933	0.3949	0	1	0.1550	0.3619	0	1

The majority of black mothers live in urban places, while only half of the non-black mothers live in cities. Typically, a high level of crime and unemployment compared to non-black areas characterizes black neighborhoods. The crime index and the unemployment rate in black areas was 8.1% and 7.8% while it was only 6.9% and 2.6% in non-black areas.

The data sample in this present study allowed me to control for several birth and labor risk conditions that could weaken the mother and the baby's health during her pregnancy. These conditions include heart and lungs problems, hypertension and many others (refer to the descriptive statistics Table 5).

Most of the studies in the health literature do not control for birth risks such as the ones mentioned earlier. In addition, they provide good instruments as some health risks are highly correlated to birth outcomes; for instance, eclampsia has been known to cause premature births. Table 5 reveals, as expected, a higher rate of chronic hypertension among African-Americans; 1% of black mothers compared to 0.5% of non-black mothers. Moreover, black babies have a lower Apgar score compared to non-black babies, 0.06% of black sample relative to 0.02% in non-black sample. The majority of the 164 hospitals in our sample are public hospitals (60%) and the rest are equally divided between for-profit and non-profit hospital, see chart 4.

CHAPTER FIVE: EMPIRICAL RESULTS

This section presents the estimation results from the full sample for the two-stage least square estimation of birth outcomes and a five percent random sample for the probit estimation of infant mortality.[11] The low incidence of infant deaths in Georgia makes it very difficult to estimate a probit model with the full sample. Nevertheless, the remaining results are shown in Appendix C.

Table 6 illustrates the determinants of the utilization of prenatal care services measured by the number of visits using a reduced form equation. The equation is separated from the birth weight equation by the supply of doctors and a crime index. Both identifiers are significant; the supply of doctors increases the demand for care in black areas while it decreases the demand for care in non-black areas, and the crime index increases the demand for care in both samples. The effects of the crime index are very large and significant. The crime index increases the demand for care by 4 to 5 visits. These effects could be partially explained by the strong relation that exists between crime and inner city poor neighborhoods where drug abuse and violent crimes are more likely to be reported than in rural or suburban areas. However, it is more likely that the crime index variable is picking up unobservable neighborhood effects; however, these effects are better controlled for in the gestation and birth weight equations.

The results show that in general younger and lesser-educated women have a lower demand for prenatal care.

[11] The ratio of infant death between black and non-black of 2:1 was maintained in the random sample.

Table 6: Prenatal and Prenatal Squared Equations from full sample

	Black		Non-black	
	PNC	**PNC SQ**	**PNC**	**PNC SQ**
	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$
Urban residence	0.0484 (0.85)	3.5012 (2.29)	-0.1251 (-4.2)	-1.7360 (1.93)
young woman	-0.1195 -2.16)	-4.9087 (-3.68)	-0.1226 (-3.22)	-2.8122 (2.56)
old woman	-0.1704 (-1.93)	-2.1774 (-0.84)	-0.0013 (-0.03)	2.5597 (0.61)
less high school	-0.7190 (-9.86)	-11.6629 (-7.43)	-0.6064 (-11.81)	-10.8331 (7.76)
some college	0.5578 (10.3)	10.9681 (7.71)	0.1551 (4.35)	0.4674 (0.44)
married	0.4454 (7.36)	8.6753 (5.52)	0.3619 (6.45)	7.1652 (4.77)
father's name missing	-0.9590 (-16.39)	-16.8877 (-12.45)	-0.8561 (-10.96)	-16.0039 (-7.97)
Medicaid	-0.7666 (-5.56)	-19.2792 (-5.41)	-0.5126 (-6.08)	-12.3180 (-5.24)
crime index[i]	**5.3837** **(5.34)**	**114.2120** **(4.42)**	**3.8627** **(4.29)**	**78.6940** **(3.27)**
ratio person to doctor[i]	**0.2299** **(16.34)**	**6.0282** **(16.9)**	**-0.1651** **(-16.65)**	**-4.9458** **(-16.57)**
population density	0.0021 (12.54)	0.0523 (13.85)	-0.0013 (-12.99)	-0.0396 (-13.72)
% black in zip code	0.0006 (11.52)	0.0127 (9.59)	-0.0007(-22.69)	-0.0248 (-25.32)
Unemployment rate	1.0791 (6.23)	26.9885 (6.03)	-0.0670 (-0.43)	-1.7018 (-0.4)
% female head HH	0.0587 (5.06)	1.2080 (4.57)	-1.1500 (-45.15)	-32.2536 (-45.98)
Medicaid* FemaleHH	-6.8741 (-5.4)	-175.5175 (-5.51)	-6.8353 (-7.43)	-194.4865 (-7.66)
per capita income	0.2130 (3.34)	4.1699 (2.44)	-0.0744 (-3.24)	-2.2874 (-3.21)
constant	7.7501 (25.27)	60.0419 (7.87)	18.5946 (93.17)	351.5868 (61.46)
	N = 30712 R^2 = 0.08	R^2 = 0.06	N = 65911 R^2 = 0.07	R^2 = 0.05

[i] corresponds to instruments variables.
t-test in parentheses

There seem to be benefits for the women to be in a relationship with the father of the baby as the coefficient on “father’s name not present” is negative and significant in the prenatal care equation. This is also supported by the significant and positive coefficient of the marital status variable. These results are consistent with the notion that the lack of father’s name on the birth certificate could indicate a lack of interest in the pregnancy or financial limitations.

Participation in the Medicaid program does not appear to be beneficial as it decreases the number of prenatal visits for pregnant women in both samples. Moreover, the interaction term significantly shows that the demand for care is even more reduced in areas with high levels of female head of household on Medicaid, up to 6 visits in both samples. However, these estimates need to be interpreted with caution due to the high correlation between Medicaid participation and unhealthy behaviors or low SES.

Due to the non-linear relation between our measures of prenatal care and birth outcomes such as birth weight and gestation, optimal prenatal care levels are obtained through the partial derivative of birth weight and gestation with respect to prenatal care. Results on these calculations are found in Table 9.

Table 7 shows the length of gestation equation results, which is the first outcome of interest. The level of prenatal care is assumed to be endogenous to this equation. The second set of columns show the model results allowing for Puma-Fixed effect. This equation is separated from the birth weight equation by a set of birth and labor risks known to have specific effects on length of gestation but not on birth weight.

The model found adverse effects of urban pollution in the black sample on length of gestation through the interaction term; both particulate measures (PM2.5 and PM10) were significant, while nitrates, carbon dioxide, and sulfates were not significant. Ai and Norton (2003) showed that the magnitude of interaction term ought to be computed differently than just using the standard marginal effects. They believe that both sign and significance varies across different values.

When all the pollutants are used then the particulates and nitrates are detrimental to gestation but carbon monoxide and sulfates have the incorrect sign. It is important to note that the correlation among pollutants is very high which makes it difficult to estimate individual effects. Moreover, the fixed effects capture the effect of living in ozone non-attainment counties. These effects could be ambiguous as there is a high correlation among non-attainment counties, industries and metropolitan areas.

These results suggest that an increase in PM10 emissions of 13, 966 short tons will result in a half-week reduction in gestation. For comparison, the average PM10 levels are 22,499 short tons and the maximum value is 41,432 short tons.

The neighborhood variables in the fixed effect model show beneficial effects of the percentage black, income and the percentage of female head of household on the length of gestation in the black sample. In contrast, population density lowers length of gestation in both samples, which is an interesting result as urban residence has been controlled for.

Marital status has positive effects while smoking and drinking have negative effects, as expected. All the birth and labor risks have significant and negative effects in both samples, from less than one week to 4 weeks. The variables which are unique to the gestation equation such as eclampsia, incompetent cervix, and others health risks have strong effects on gestation in both samples, between two to five fewer weeks. Additionally, black women with chronic hypertension have shorter gestation, up to one week, although it is only half a week shorter in the non-black sample. Women with previous miscarriages and diabetes have babies with a shorter length of gestation regardless of race.

A large number of Puma-fixed effects are significant in both samples; however, they are more beneficial in the non-black sample than in the black sample. These neighborhood effects are partially explained by the level of racial segregation (housing, particularly) in the Atlanta region. These results suggest that location matters.

Table 8 displays the results for the birth weight equation estimated by IV methods. The length of gestation, prenatal care and prenatal care squared are assumed to be endogenous in the weight equation. Both weight gained during pregnancy and parity are unique to this model. They identify the birth weight variable, which is endogenous to the infant mortality equation. The model does find some effects of air pollution on birth weight in the non-black sample and there are fewer Puma-fixed effects that are significant than in previous estimations.[12]

The model found that an increase in PM10 levels decreases birth weight by 20 grams. It would take an increase of 45, 495 short tons to cause a 100 grams decrease in birth weight, which represents a very large change in emissions. In fact, this increase is twice the PM mean, or to view it differently it is slightly greater than the maximum PM emission in our sample.

The coefficients on parity and weight gain are positive and significant. The parity result is consistent with previous findings that first births have a higher probability of lower birth weight.

Prenatal care has ambiguous results in the black sample while it is measured to have only beneficial effects in the non-black sample without fixed effects. This result brings into question

[12] The f test performed on the Puma-Dummies was only significant in the non-black sample; refer to Table 8.

the productiveness of prenatal care on birth weight for black mothers; this might result from the inadequate control for the level of quality in care received by those women.

Table 9 shows the optimal values for prenatal care visits for the length of gestation and birth weight equations. The results show that with respect to gestation, black mothers should receive 10 visits, and with respect to birth weight non-black mothers should receive 13 visits. Some values were not computed for black and non-black mothers as the effects of prenatal care were not significant, see Tables 7 and 8.

Table 9: Quadratic Prenatal Care Values

Optimal number of visits for gestation length			
black		Non-black	
IV	fixed	IV	fixed
10	**10**		
Optimal number of visits for birth weight			
black		Non-black	
IV	fixed	IV	fixed
		13	**13**

In addition, neighborhood characteristics do not seem to matter in the birth weight equation as only a few variables such as population density and the Medicaid interaction term are significant; infants living in zip codes with a large number of female head of households show a lower birth weight by 200 grams in the non-black sample.

A lesser-educated Georgia woman who smokes is more likely to have an underweight baby regardless of race. Hypertension has negative effects in both samples, up to 90 grams. On the other hand, diabetes increases birth weight by more than 250 grams in both samples. As expected, female babies are smaller than male babies; the difference between the two is close to 110 grams.

The effects of smoking are also strong and detrimental to birth weight as woman that smoke during their pregnancies will have babies that are 85 to 190 grams smaller, in the black and non-black samples respectively. This study also found negative effects of hydramnios on birth weight in both samples, as the coefficient is negative and significant, between 80 to 140 grams.

Unlike Currie and Neidell (2004), this analysis found moderate effects of air pollution on birth weight and length of gestation. However, this study follows a long list of epidemiological studies that found a positive link between low birth weight and air pollution such as (Liu et al. 2003; Maisonet et al. 2004; Parker, J.Woodruff, Basu, and C.Schoendorf 2005; Wang et al. 1997) examined also the link between low birth weight and air pollution using birth certificates from California. Their study found that women residing in neighborhoods with high levels of particulate matters (PM2.5) are more likely to give birth to babies 30 grams smaller. However, similarly to Currie and Neidell (2004), they used different pollutants measurements than this study. For instance, Currie and Neidell (2004) used a distance weighted pollution average for each trimester of pregnancy using the zip code of residence. These measurement differences make comparisons among epidemiological studies very difficult.

Table 10 shows the probit results for estimating the probability of infant mortality from a five percent random sample. The dependent variable is equal to one if the infant died within a year, and equal to zero, otherwise.

Table 10: Probit Results from random sample

	Black		Non-black	
	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$
	1	**2**	**3**	**4**
predicted weight[e]	-0.0002 (-4.39)	-0.0003 (-5.9)	-0.0003 (-6.78)	-0.0004 (-7.68)
young woman	0.0640 (0.76)	0.0644 (0.76)	-0.0154 (-0.22)	-0.0169 (-0.25)
old woman	0.0173 (0.1)	0.0559 (0.35)	0.0262 (0.23)	0.0273 (0.24)
less high school	0.1123 (0.21)	0.0980 (1.06)	0.0115 (0.13)	-0.0086 (-0.1)
some college	-0.1304 (-1.44)	-0.1435 (-1.59)	-0.1208 (-1.69)	-0.1304 (-1.85)
married	-0.1221 (-1.23)	-0.1344 (-1.36)	-0.1536 (-1.7)	-0.1412 (-1.57)
father's name missing	-0.1772 (-2.09)	-0.1812 (-2.15)	-0.1138 (-1.01)	-0.1388 (-1.24)
female (sex of baby)	-0.0539 (-0.73)	-0.0539 (-0.74)	-0.1266 (-2.13)	-0.1343 (-2.3)
Medicaid	0.4791 (1.98)	0.4764 (1.98)	-0.1551 (-1.05)	-0.1264 (-0.89)
smoke	0.0196 (0.13)	0.0145 (0.1)	0.0223 (0.27)	0.0159 (0.2)
drink	0.1993 (0.48)	0.3199 (0.87)	-0.5969 (-1.4)	-0.5090 (-1.17)
Heart problems			1.3601 (3.45)	1.3236 (3.52)
Lung problems	0.8321 (2.22)	(1.1095) (2.42)		
Hypertension*diabetes			-0.0273 (-0.04)	-0.0938 (-0.16)
Congenital anomalies[i]	**0.4032** **(1.95)**		**0.8206** **(6.52)**	
Abnormal conditions at birth[i]	**0.5840** **(3.99)**		**0.5493** **(5.22)**	
Bad apgar score[i]	**1.9387** **(8.73)**	**2.0893** **(9.29)**	**2.0994** **(9.79)**	**2.3478** **(10.75)**
Moderate apgar score[i]	**0.2909** **(2.31)**	**0.4481** **(3.68)**	**0.4211** **(4.11)**	**0.5924** **(5.61)**
percent county beds	-0.0009 (-3.65)	-0.0009 (-3.94)	-0.0003 (-2.82)	-0.0004 (-3.02)
unemployment rate	0.1705 (4.41)	0.1787 (4.63)	0.3135 (6.84)	0.3346 (7.34)
population density	0.0026 (5.98)	0.0026 (6.17)	0.0009 (4.57)	0.0010 (5.05)

percent pop public asst	12.1730 (3.78)	12.1028 (3.8)	5.4662 (1.83)	6.6140 (2.29)
% black in zip code	-1.9376 (-5.14)	-1.9748 (-5.34)	-1.1706 (-3.33)	-1.2408 (-3.52)
% female head HH	6.2095 (2.9)	6.0859 (2.92)	2.6867 (1.38)	2.8854 (1.51)
Medicaid* FemaleHH	-3.7967 (-2.3)	-3.7068 (-2.29)	1.4620 (0.92)	1.3350 (0.87)
per capita income	0.1576 (1.47)	0.1453 (1.34)	-0.1226 (-1.23)	-0.0936 (-0.98)
warm season	-0.0611 (-0.83)	-0.0438 (-0.6)	0.1098 (1.87)	0.1025 (1.77)
particulate matter size10	**0.6605** **(3.55)**	**0.5854** **(3.25)**	**1.1508** **(12.38)**	**1.0885** **(12.89)**
urban residence	-0.4538 (-2.29)	-0.5126 (-2.62)	-0.3661 (-2.36)	-0.3552 (-2.37)
Urban*PM10	**0.0775** **(0.55)**	**0.1108** **(0.79)**	**0.0299** **(0.29)**	**0.0165** **(0.17)**
Non-attainment county	-1.3633 (-9.38)	-1.2436 (-9.46)	-0.7181 (-7.43)	-0.6056 (-6.72)
profit	0.5912 (3.86)	0.4936 (3.42)	0.1016 (1.02)	0.0003 (0)
Non-profit	-0.5822 (-5.74)	-0.5105 (-4.95)	-0.5356 (-5.36)	-0.4673 (-4.92)
constant	-4.1614 (-6.2)	-3.9008 (-5.82)	-2.5568 (-6.83)	-2.4768 (-6.62)
	N = 4357 LOG LIKELIHOOD = -671.7276 MFX at mean = 0.038		N = 9752 LOG LIKELIHOOD = -999.0328 MFX at mean = 0.017	

[i] corresponds to instruments variables.
[e] corresponds to endogenous variables.

The model captures strong and negative effects of particulate matters (PM10) in both samples, on infant mortality, even though the interaction term that captures urban pollution was not significant. Indeed, all the pollutants show significant and positive effects in all the estimations using the five percent random sample, except for CO in the black sample. In addition, an increase of 1,515 short tons in the IV model or of 869 short tons in the fixed effects model could result in a 10% increase in infant mortality in the state of Georgia. These results suggest that the effects of air pollution on infant mortality are substantial which suggests that some government intervention could help to alleviate the problem. When the all pollutants are introduced in the equation then PM10 and nitrates have positive signs while CO and SO2 have the opposite sign. This could be a result of high collinearity among pollutants.

In order, to test whether these results are driven by the inclusion of variables measuring congenital and abnormal conditions, the model was estimated both with and without those variables. Columns 2 and 4 of Table 10 show that indeed the results for the pollution variable are robust as the effects of air pollution are still strong and significant.

Unexpectedly, the effects of predicted weight on infant mortality are similar in both samples. Low birth weight has been widely used the medical literature as a proxy for infant health. These results show that birth weight has only a minor effect on the probability of infant mortality. This result is consistent with Almond, Lee, and Chay (2002), which examined the usefulness of birth weight as a proxy to infant health. They concluded that indeed low birth weight maybe misleading in assessing infant survival, and that the Apgar score may be more associated with infant mortality.

The significance of the variable urban residence and pm2.5 non-attainment counties in both samples implies an improvement in mortality outcomes in urban settings relative to rural areas, which is consistent with literature on rural health.

The results imply that few demographic characteristics, such as marital status, and education appear to matter, whereas most of the neighborhood variables are significant. It suggests that neighborhood variables together provide a better picture of a mother's socioeconomic status than do single demographic variables such as marital status and education.

The variables unique to this equation include the Apgar score, congenital and abnormal conditions at birth. The unemployment rate, the percentage of individuals on public assistance, and population density appear to increase the mortality rate. In fact, a low Apgar score, congenital abnormalities, the level of poverty measured by the number of people receiving public assistance, and the level of unemployment are major predictors of infant mortality. This result is confirmed by the large values of their respective marginal effects in Table 11.

Table 11 displays the marginal effects, which give an indication of the strength of the relation existing between the dependent and independent variables from the probit estimation. Overall, these effects are quite small as expected due to the small incidence of infant deaths. The units of measurement for the pollutants are in short tons which correspond to 2, 000 pounds, thus for every short ton increase in particulate matter (PM10), the probability of death increase by 5% and 4% in the black and non-black sample respectively.

The results also indicate that birth weight has a small effect on infant mortality as the magnitude of its effects range from 0.00002 and 0.00001 for blacks and non-blacks respectively. When the marginal effects are computed for every 1, 000 grams then the marginal effects for birth weight is 0.2 which means that for every 1, 000 grams increase in weight, infant mortality drops by 2%.

Table 11: Probit Marginal Effects Results from random sample

	Black		Non-black	
	DY/DX	Means	DY/DX	Means
predicted weight	-0.00002	2966.71000	-0.00001	3296.20000
young woman	0.00527	0.55832	-0.00065	0.41509
old woman	0.00145	0.07499	0.00114	0.07998
less high school	0.00990	0.18749	0.00049	0.18817
some college	-0.01038	0.32919	-0.00504	0.44114
married	-0.00973	0.32160	-0.00716	0.79348
father's name missing	-0.01408	0.36301	-0.00437	0.09229
female (sex of baby)	-0.00445	0.48194	-0.00534	0.48329
Medicaid	0.03486	0.67426	-0.00635	0.39315
smoke	0.00165	0.05797	0.00096	0.17955
drink	0.01957	0.01035	-0.01388	0.00615
Heart problems			0.20639	0.00185
Lung problems	0.13500	0.00092		
Hypertension*diabetes			-0.00112	0.00113
Congenital anomalies	0.04670	0.01679	0.07814	0.01856
Abnormal conditions at birth	0.07374	0.08098	0.03892	0.05794
Bad apgar score	0.51182	0.02554	0.46832	0.00933
Moderate apgar score	0.03022	0.05452	0.02709	0.03025
percent county beds	-0.00007	75.55230	-0.00001	76.84240
unemployment rate	0.01411	8.54747	0.01326	2.83820
population density	0.00021	531.14700	0.00004	460.11700
percent pop public asst	1.00718	0.04811	0.23121	0.02923
% black in zip code	-0.16031	0.47899	-0.04951	0.22470
% female head HH	0.51376	0.11979	0.11364	0.07886
Medicaid* FemaleHH	-0.31414	0.08267	0.06184	0.03105
per capita income	0.01304	1.66221	-0.00519	1.87526
warm season	-0.00507	0.51898	0.00466	0.49569
particulate matter size10	0.05465	1.14039	0.04868	0.99175
urban residence	-0.04944	0.83966	-0.01590	0.50964
Urban*PM10	0.00641	0.97584	0.00126	0.51513
Non-attainment county	-0.12845	0.49298	-0.03409	0.52994
profit	0.07409	0.09501	0.00459	0.19852
Non-profit	-0.03850	0.25719	-0.01800	0.26272

Indeed, birth weight has been widely used in previous research as a predictor of negative health outcomes such as mortality, mental retardation but its effects are rather small in terms of predicting infant mortality. Perhaps the Apgar score is one of the best predictor of infant mortality and is possibly the best medical indicator for assessing the survival of the infant. Moreover, women living in neighborhoods with a high percentage of the population receiving public assistance, also show a substantial increase in the risk of their infants dying before their first birthday.

Finally, Table 12 shows the probability of death for an infant with a birth weight of 2,500 grams based on different characteristics of the mother, such as age, birth risks, and Medicaid status. Others covariates are set at their sample mean values. These profiles clearly demonstrate that:

Given average values for others covariates, predicted probabilities of infant mortality for a black mother on Medicaid drastically increases to 17% compared to 1% for non-black mothers, regardless of age. In addition, the profiles confirm the positive aspects of education and marital status and the negative effects of smoking on infant mortality.

Low birth weight black infants are twice as much likely to die than non-black infants, given the average values of others covariates. Women living in rural areas are more likely to lose their low birth weight infants relative to women living within city limits. The picture is even more striking when race is introduced; the probability of death for an infant with an older black mother involved in “risky” behaviors such as drinking and smoking while pregnant is 40% in rural areas and 26% in urban areas compared to less than 1% for non-blacks. And finally, women living in high pollution areas are also more likely to lose their infants than women living in nonpolluted neighborhood. The profiles show that the probability increases by 20% in both samples.

Table 12: Estimated Probabilities using profiles

Profiles		Black	Non-black
	Effects of education		
A	Less than high school	0.0986	0.0202
	Increase education to college	0.0627	0.0146
B	Increase education to college	0.0394	0.0162
	Effects of Medicaid Insurance		
A	Become Medicaid recipient	0.1776	0.0133
B	Become Medicaid recipient	0.1658	0.0148
	Effects of Marriage and Smoking		
A	Marriage	0.0638	0.0134
	smoking	0.0832	0.0208
	Effects of High risks and residence		
Young	Move to rural area	0.4507	0.008
	urban	0.2762	0.003
Older woman	Move to rural area	0.4324	0.009
	urban	0.2609	0.003
	Effects of 40% change in PM10 levels		
A	low	0.0171	0.001
A	high	0.2075	0.1853

Base case characteristics for A are: 20 years old, unmarried, urban, and birth weight of 2500g
Base case characteristics for B are: 45 years old, unmarried, urban, and birth weight of 2500g
Base case characteristics for High risk are: unmarried, Medicaid, drink, smoke and birth weight of 2500g

These results are confirmed using another set of characteristics summarized in Table 13. Table 13 used a different set of characteristics such as older woman, married with some college, with a household income of $40,000, a birth weight of 3,000 grams and living in an urban area with very low air pollution levels but found the same effects of rural residence, pollution effects, Medicaid participation and the effects of education. In summary, the model found that the probability of death is 0.0021 and 0.00009 for the black and the non-black sample respectively. These probabilities increased by 75% if the mother moved in a rural residence or if she became a Medicaid recipient. The Apgar score and air pollution effects are even larger as the probability increase is between 80 to 90% in both samples.

Table 13: Estimated Probabilities using different profiles

Profile: 25 years old, married, urban, college, $40, 000, low pm10 levels (0.11 for BLACK, 0.09 for NON-BLACK), Birth weight (3000g).			**Black**	**Non-black**		
			0.0021	0.00009		
			Rate		**Ratio**	
Impact of a change			**B**	**NB**	**B**	**NB**
Education: Less than high school	0.0045	0.00016	52.19%	40.33%	2	1 2/3
Rural residence	0.0085	0.00039	74.86%	75.69%	4	4 1/9
Medicaid insurance	0.0086	0.00005	75.36%	75.36%	4	1/2
Average pm10 levels (1.14 for B, 0.99 for NB)	0.0144	0.00346	85.17%	97.28%	6 3/4	36 4/5
Bad Apgar Score	0.1776	0.00046	98.80%	79.55%	83 2/5	4 8/9

CHAPTER SIX: CONTRIBUTION AND LIMITATIONS

This study adds to the current literature by extending the Rosenzweig and Schultz (1983) model by assuming that the place of residence of the mother captures both the environment surrounding the pregnant mother but also captures unobserved housing, and neighborhood characteristics which have been known to affect birth outcomes in the medical literature. Finally, this study provides extensive evidence from the state of Georgia on the impact of air pollution on infant health outcomes.

There are a number of econometric challenges in this work. Several important variables are potentially endogenous, including the demand for prenatal care of the mother, and the length of gestation. This analysis attempted to account for these issues. There are several possible endogenous variables such as smoking, abortion, and Medicaid status that this study did not address due to lack of good instruments.

Future research should be able to acquire more infant-level information such as head circumference, and height, so that fetal growth could be better determined. Another set of variables that would enrich this study would be those describing the type of housing, to better assess the level of indoor pollution. Due to the likelihood of pollution spillovers across Georgia counties, some spatial econometrics techniques should probably be used. Finally, the use of the causes and timing of death should also provide additional information to the researcher to better assess the probability of death within one year.

Policy Implications and Conclusion

This research provided evidence of the effects of air pollution on infant mortality using a dataset from the State of Georgia. I also find some evidence that air pollution affects birth weight and length of gestation. Based on these results, there does appear to be a need to develop policies to prevent low birth weight and premature infants from air pollution.

The results can be summarized in three main findings. First, air pollution increases infant mortality. The study found a substantial effect of PM2.5, PM10 and NOX on infant mortality, while the results of CO and SO2 are more ambiguous. These estimates are large which suggest that environmental policy is needed to alleviate these effects.

A second finding of this study is the effects of air pollution on birth weight and length of gestation. The study found detrimental effects of particulate matters and nitrogen oxides on birth weight and gestation for the sample of non-black mothers. These results suggest that policy makers should consider action to alleviate the negative effects of air pollution on infant health, even though the effects on weight and gestation were much smaller than the effects found on infant mortality. Nevertheless, these effects suggest that current standards, which are based on adult physiology, should be revised or at least revisited.

A third finding of this analysis is the role of rural health in explaining the racial differential between infant mortality rates. The estimated profiles showed a significant difference between the health of pregnant women and their children in an urban place relative to a rural location. The role of age has been long used to explain the differential between blacks and non-blacks women health outcomes but these effects disappeared once urban and non-urban residence are accounted for. This study showed that rural health should be closely monitored and that any policy aiming at improving health outcomes should definitely consider a comprehensive examination of rural institutions.

Policies related to the regulation of environmental pollutants have been very controversial. For instance, the "Clear Skies Initiative" of the current administration has been criticized as it lowers current EPA standards by allowing old power plants not to upgrade their equipment in order to meet EPA's standards, according to the American Lung Association (2003). Moreover, critics argue that the new Bush initiative will increase the emissions of particulate matters and nitrogen, which are related to smog and particulate matters, and found to be detrimental to infant and adult health.

Power plants are vital in providing energy but they have been recognized to be major emitters of sulfur dioxide and nitrogen oxides; however, there are also key contributors to economic development. The challenge of government policy is to find an equitable balance between public health and economic growth. In order to better understand the health effects of environmental pollutants, health policy makers need more epidemiological studies of this kind that investigate the harmful effects of air pollution on one of the most sensitive group in our society.

There are several possible solutions that could address the health issues highlighted in this study. First, diminish the usage of fossil fuels and augment the use of alternate and cleaner fuels that are less toxic. Second, strengthen current air standards and base them on infant physiology. Third, target the different industries that are responsible for most of the emissions such as utilities and automobile companies. Finally, provide economic incentives to spur new technological research and compliance.

Despite the numerous empirical challenges in this research into the effects of air pollution on infant health, this study quantified the impact of air pollution while controlling for a rich set of covariates. These findings are interesting and perhaps can lead to further research in this area.

Table 7: Length of Gestation Equation from full sample

	Black	N = 29195	**Non-black**	N = 63509
	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$
	IV	**Fixed**	**IV**	**Fixed**
prenatal care[e]	0.7366 (4.86)	0.7338 (4.67)	0.0121 (0.1)	-0.0601 (-0.51)
prenatal squared[e]	-0.0373 (-5.15)	-0.0372 (-4.88)	-0.0010 (-0.23)	0.0018 (0.43)
weight gain	0.0226 (21.6)	0.0226 (21.63)	0.0148 (23.61)	0.0150 (23.92)
young woman	-0.1354 (-3.41)	-0.1283 (-3.18)	-0.0407 (-2.07)	-0.0365 (-1.87)
old woman	-0.0340 (-0.62)	-0.0320 (-0.58)	-0.0252 (-0.91)	-0.0399 (-1.44)
less high school	0.1451 (2.67)	0.1402 (2.58)	0.0448 (1.27)	0.0028 (0.08)
some college	0.0656 (1.69)	0.0700 (1.79)	0.0296 (1.2)	0.0481 (1.94)
married	0.1724 (3.85)	0.1672 (3.72)	0.1061 (3.13)	0.1282 (3.78)
female (sex of baby)	-0.0499 (-1.75)	-0.0534 (-1.88)	0.0887 (5.94)	0.0865 (5.81)
Medicaid	0.0936 (1.03)	0.0839 (0.9)	0.1051 (2.5)	0.0705 (1.67)
smoke	-0.3807 (-5.53)	-0.3758 (-5.47)	-0.1906 (-7.63)	-0.1787 (-7.15)
Diabetes	-0.2003 (-1.92)	-0.1882 (-1.8)	-0.3771 -6.89)	-0.3780 (-6.92)
hydramnios	-1.0453 (-6.64)	-0.9752 (-6.2)	-1.0669 (-11.73)	-1.0221 (-11.26)
chronic hypertension	-1.2647 (-8.06)	-1.2402 (-7.92)	-0.7662 (-6.66)	-0.7590 (-6.61)
hypertension	-0.8217 (-9.01)	-0.8014 (-8.8)	-0.9268 (-20.54)	-0.9272 (-20.59)
Hypertension*diabetes	-0.2679 (-0.69)	-0.2496 (-0.65)	0.4570 (1.47)	0.4849 (1.56)
parity	-0.0507 (-4.27)	-0.0448 (-3.77)	-0.0688 (-8.78)	-0.0677 (-8.65)
population density	-0.0004 (-9.32)	-0.0007 (-12.36)	-0.0002 (-9.28)	-0.0003 (-11.69)
% black in zip code	0.0983 (0.85)	0.1662 (1.14)	-0.1930 (-2.42)	-0.1311 (-1.39)

% female head HH	-0.9032 (-1.14)	-0.9942 (-1.13)	0.3545 (0.74)	0.1776 (0.36)
Medicaid*FemaleHH	0.3587 (0.57)	0.5290 (0.83)	0.2635 (0.57)	0.5881 (1.26)
per capita income	0.0494 (1.25)	0.0030 (0.07)	0.0450 (3.6)	0.0068 (0.4)
warm season	0.2178 (6.78)	0.1368 (3.95)	0.0585 (4.8)	0.0157 (1.17)
part matter size10	**-0.0290 (-1.02)**	**-0.0288 (-1.01)**	**0.0127 (0.85)**	**0.0144 (0.97)**
Urban residence	0.0743 (1.15)	0.1582 (2.38)	-0.0572 (-2.02)	-0.0331 (-1.16)
Urban*PM10	**-0.0399 (-1.65)**	**-0.0599 (-2.4)**	**0.0238 (2.25)**	**0.0090 (0.83)**
Non-attainment	-0.0210 (-0.43)	-0.3624 (-5.42)	-0.0097 (-0.4)	-0.2201 (-7.14)
profit	0.1857 (3.98)	0.1860 (3.8)	0.0473 (2.04)	0.0680 (2.83)
non-profit	0.1202 (3.02)	0.1601 (3.7)	0.2482 (11.01)	0.2650 (10.88)
Eclampsia[i]	**-1.9772 (-8.16)**	**-2.0325 (-8.41)**	**-1.8384 (-16.14)**	**-1.8458 (-16.23)**
Incompetent cervix[i]	**-3.7998 (-15.97)**	**-3.7632 (-15.85)**	**-2.8120 (-18.01)**	**-2.8126 (-18.05)**
Extra bleeding[i]	**-0.0811 (-0.21)**	**-0.0578 (-0.15)**	**-1.1536 (-7.48)**	**-1.1721 (-7.61)**
Premature rupture[i]	**-4.4509 (-50.68)**	**-4.3963 (-50.11)**	**-2.3752 (-46.88)**	**-2.3608 (-46.68)**
Abruptio placenta[i]	**-3.9321 (-20.72)**	**-3.9256 (-20.75)**	**-2.5170 (-20.5)**	**-2.5210 (-20.58)**
Placenta previa[i]	**-3.6999 (-12.44)**	**-3.6256 (-12.21)**	**-2.3732 (-17.99)**	**-2.3464 (-17.82)**
Others bleeding[i]	**-0.5136 (-2.07)**	**-0.6043 (-2.44)**	**-0.1496 (-1.36)**	**-0.1619 (-1.48)**
Miscarriage[i]	**-0.2676 (-7.06)**	**-0.2667 (-7.05)**	**-0.1139 (-5.84)**	**-0.1129 (-5.79)**
Abortion	-0.0416 (-0.9)	-0.0673 (-1.46)	-0.0457 (-1.55)	-0.0525 (-1.78)
drink	-0.6481 (-4.35)	-0.6506 (-4.38)	0.0855 (1.01)	-0.0985 (-1.46)
Fayette Coweta Spalding		-0.3075 (-2.5)		-0.1245 (-1.83)
Paulding Bartow		-0.2515 (-1.75)		-0.1026 (-1.6)
Henry Rockdale		-0.0460 (-0.41)		0.1133 (0.32)

Lithonia		0.0064 (0.05)		0.1508 (2.18)
Marietta		-0.0462 (-0.37)		0.1251 (1.37)
Smyrna		-0.0027 (-0.02)		0.0753 (0.57)
Austell Mableton		0.3532 (1.61)		0.0977 (1.38)
Acworth Kennesaw		0.1224 (0.66)		-0.0700 (-1.06)
Forsyth hall		-0.3183 (-1.44)		0.1671 (1.56)
st mountain		0.0865 (1.03)		0.1903 (1.77)
Avondale		-0.1604 (-1.17)		0.1693 (2.29)
Doraville druid hill		0.1214 (1.07)		0.1302 (1.63)
Alpharetta		0.0594 (0.2)		0.1942 (2.48)
sandy spring		0.2632 (1.37)		0.0208 (0.22)
midtown		-0.0683 (-0.79)		0.2279 (1.97)
downtown		0.0039 (0.04)		-0.0560 (-0.45)
college park		-0.1217 (-1.23)		0.1611 (2.05)
Lilburn Norcross		0.4125 (2.65)		0.0894 (1.25)
Lawrenceville		0.0900 (0.53)		-0.1288 (-1.44)
Snellville		0.0191 (0.16)		0.0739 (1.08)
Duluth Suwannee		0.2741 (1.85)		-0.7227 (-10.15)
savannah		-1.1073 (-10.1)		-0.3189 (-4.46)
northeast		-0.6644 (-6.09)		-0.3250 (-4.92)
northwest		-0.6890 (-5.5)		-0.4913 (-7.55)
central		-0.9360 (-9.79)		-0.4709 (-6.83)
southwest		-0.8321 (-7.89)		-0.4690 (-6.57)
south		-1.0019 (-9.21)		-0.0985 (-1.46)
constant	35.1678 (49.91)	36.2007 (50.11)	38.5732 (54.61)	39.5455 (55.09)
	$R^2 = 0.152$	$R^2 = 0.159$	$R^2 = 0.086$	$R^2 = 0.09$

[i] corresponds to IV, [e] corresponds to endogenous variables t-test in parentheses

Table 8: Birth Weight Equation from full sample

	Black		Non-black	
	IV	FIXED	IV	FIXED
	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$
Gestation[e]	193.9164 (70.23)	194.2405 (69.6)	211.1527 (56.9)	211.0930 (56.72)
prenatal care[e]	-1.0426 (-0.04)	3.3925 (0.12)	76.9039 (2.73)	68.8092 (2.42)
prenatal squared[e]	0.2950 (0.23)	-0.0109 (-0.01)	-3.0301 (-2.98)	-2.6876 (-2.62)
weight gain[i]	4.4465 (21.07)	4.4377 (21.02)	5.2875 (31.4)	5.2698 (31.21)
Parity[i]	26.5862 (12.12)	26.6811 (12.15)	45.5711 (23.69)	45.3755 (23.59)
young woman	-29.5167 (-4.16)	-30.1894 (-4.18)	-15.1646 (-3.26)	-15.3800 (-3.31)
old woman	-14.0211 (-1.32)	-13.2418 (-1.25)	-7.8937 (-1.17)	-7.8687 (-1.16)
less high school	-18.4154 (-1.91)	-17.8708 (-1.85)	-20.3604 (-2.4)	-18.4635 (-2.17)
some college	9.9440 (1.42)	10.2427 (1.45)	13.3209 (2.26)	13.0815 (2.2)
married	44.4187 (5.54)	44.1467 (5.47)	43.1203 (5.39)	42.9792 (5.35)
female (sex of baby)	-112.7089 (-22.08)	-112.6494 (-22.05)	-131.7891 (-37.15)	-131.6104 (-37.13)
Medicaid	14.2579 (0.87)	15.3564 (0.91)	-13.8193 (-1.37)	-11.7623 (-1.16)
smoke	-148.1549 (-12.13)	-146.9552 (-12.02)	-186.9700 (-31.38)	-188.4294 (-31.58)
Diabetes	285.9770 (11.81)	285.0975 (11.79)	215.1266 (13.45)	216.3510 (13.53)
hydramnios	-139.1150 (-4.23)	-140.2584 (-4.26)	-82.2922 (-3.4)	-84.0026 (-3.47)
chronic hypertension	-79.0731 (-2.65)	-80.5482 (-2.7)	-16.7302 (-0.6)	-17.1316 (-0.62)
hypertension	-100.2614 (-5.29)	-100.9211 (-5.33)	-64.3242 (-5.32)	-64.6073 (-5.35)
Hypertension*diabetes	-166.9257 (-1.8)	-162.6378 (-1.76)	-101.0329 (-0.92)	-102.1061 (-0.93)
population density	0.0301 (3.42)	0.0355 (3.68)	0.0253 (4.09)	0.0313 (4.68)
% black in zip code	-23.8166 (-1.13)	-13.0883 (-0.49)	-30.4314 (-1.58)	-34.3137 (-1.51)

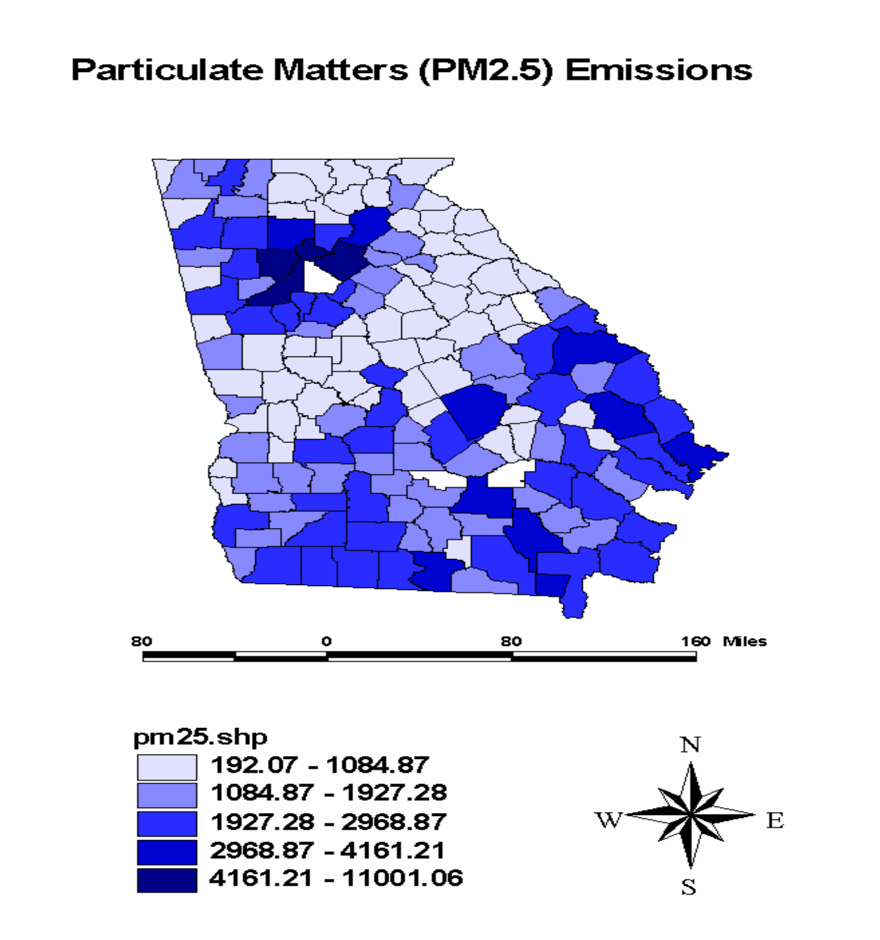
% female head HH	162.3679 (1.12)	206.4374 (1.29)	150.3157 (1.32)	148.2957 (1.26)
Medicaid*FemaleHH	-140.2656 (-1.24)	-159.8744 (-1.39)	-217.3623 (-1.94)	-222.1863 (-1.97)
per capita income	3.0627 (0.42)	4.4221 (0.53)	-1.7343 (-0.61)	5.9747 (1.55)
warm season	-5.5066 (-1.08)	-5.4915 (-1.07)	7.7397 (2.2)	7.7173 (2.19)
part matter size10	**-6.5739** **(-1.12)**	**-4.5909** **(-0.73)**	**-21.9869** **(-7.63)**	**-20.7971** **(-6.53)**
Urban residence	-6.4070 (-0.56)	-16.2416 (-1.36)	-1.4051 (-0.21)	-3.9688 (-0.58)
Urban*PM10	1.6643 (0.38)	6.0045 (1.33)	-0.8516 (-0.34)	0.8373 (0.33)
Non-attainment	2.9763 (0.34)	11.6170 (1.01)	12.1578 (2.12)	22.7687 (3.1)
profit	-4.5532 (-0.55)	0.0433 (0.01)	7.4894 (1.39)	6.8541 (1.22)
non-profit	15.8813 (2.26)	17.1602 (2.28)	9.0525 (1.69)	13.5927 (2.34)
Fayette Coweta Spalding		-16.9871 (-0.75)		19.9360 (1.22)
Paulding Bartow		11.3550 (0.42)		32.6956 (1.99)
Henry Rockdale		-2.9360 (-0.14)		25.1334 (1.62)
Lithonia		-24.7488 (-1.13)		-19.5072 (-0.21)
Marietta		-2.8038 (-0.12)		5.6166 (0.34)
Smyrna		11.9527 0.42)		6.3385 (0.29)
Austell Mableton		12.4818 (0.34)		43.7648 (1.45)
Acworth Kennesaw		-37.7425 (-1.14)		35.4938 (2.08)
Forsyth hall		-5.1362 (-0.12)		8.0813 (0.51)
st mountain		-15.1642 (-0.99)		-5.4108 (-0.2)
Avondale		-49.5205 (-1.98)		-21.4160 (-0.85)
Doraville druid hill		-26.7228 (-1.29)		-19.2172 (-1.09)
Alpharetta		39.0947 (0.65)		-6.2771 (-0.33)
sandy spring		18.2718 (0.51)		-15.8602 (-0.85)
midtown		-31.4194 (-1.99)		-21.2493 (-0.97)

downtown		-28.1643 (-1.66)		10.1868 (0.36)
college park		-30.4054 (-1.7)		36.4695 (1.2)
Lilburn Norcross		15.4116 (0.55)		6.6595 (0.36)
Lawrenceville		35.9316 (1.16)		21.4355 (1.25)
Snellville		-6.7537 (-0.32)		48.3539 (2.21)
Duluth Suwannee		-32.3380 (-1.23)		2.2813 (0.14)
savannah		22.0642 (1.13)		47.1843 (2.74)
northeast		-13.0682 (-0.67)		17.7864 (1.03)
northwest		3.6289 (0.16)		17.9933 (1.12)
central		15.5128 (0.89)		49.4768 (3.13)
southwest		23.6082 (1.24)		27.2762 (1.62)
south		26.0274 (1.33)		62.4527 (3.61)
constant	-4501.436 (-28.59)	-4546.714 (-27.85)	-5430.788 (-24.18)	-5439.8720 (-23.69)
	N= 29195		N = 63509	
	R^2 = 0.543	R^2 = 0.544	R^2 = 0.4280	R^2 = 0.4287
		F (25, 29137) = 1.19		F (27, 63541) = 2.68
		Prob > F = 0.2244		Prob> F = 0.0000

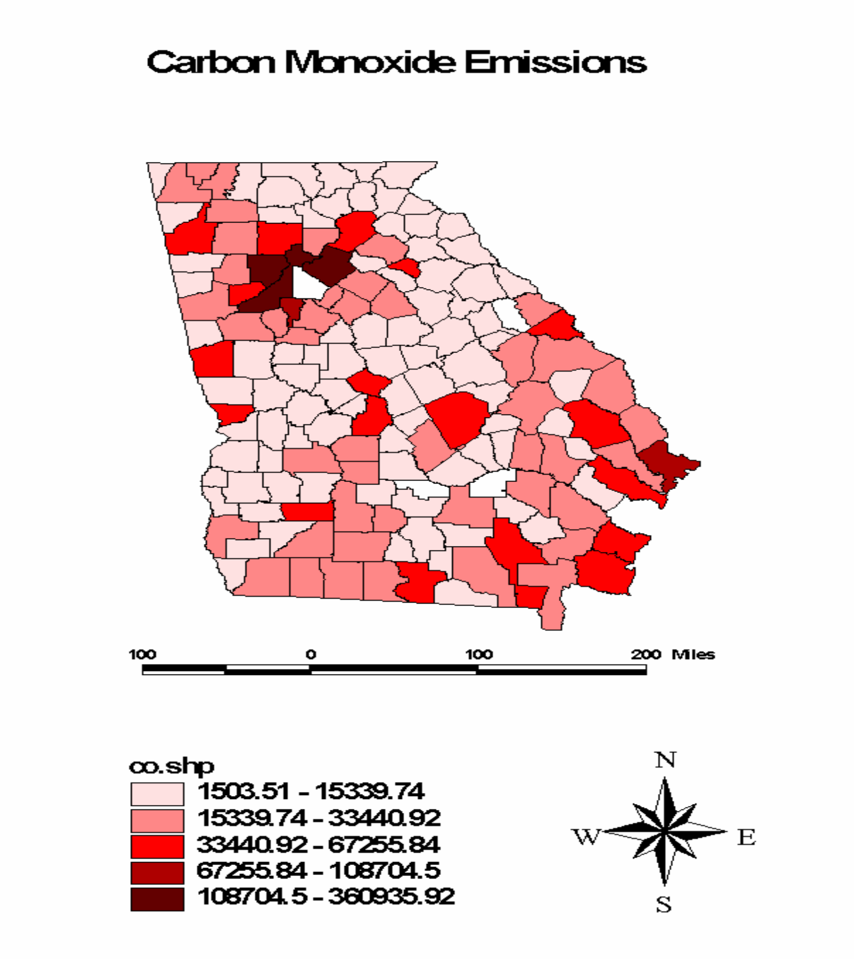
[i] corresponds to instruments variables.

[e] corresponds to endogenous variables.

t-test in parentheses and Puma base is Clayton county.



MAP 1: PM2.5 Emissions by County



MAP 2: CO Emissions by County

Chart 1: Birth Outcomes by Age and by Race

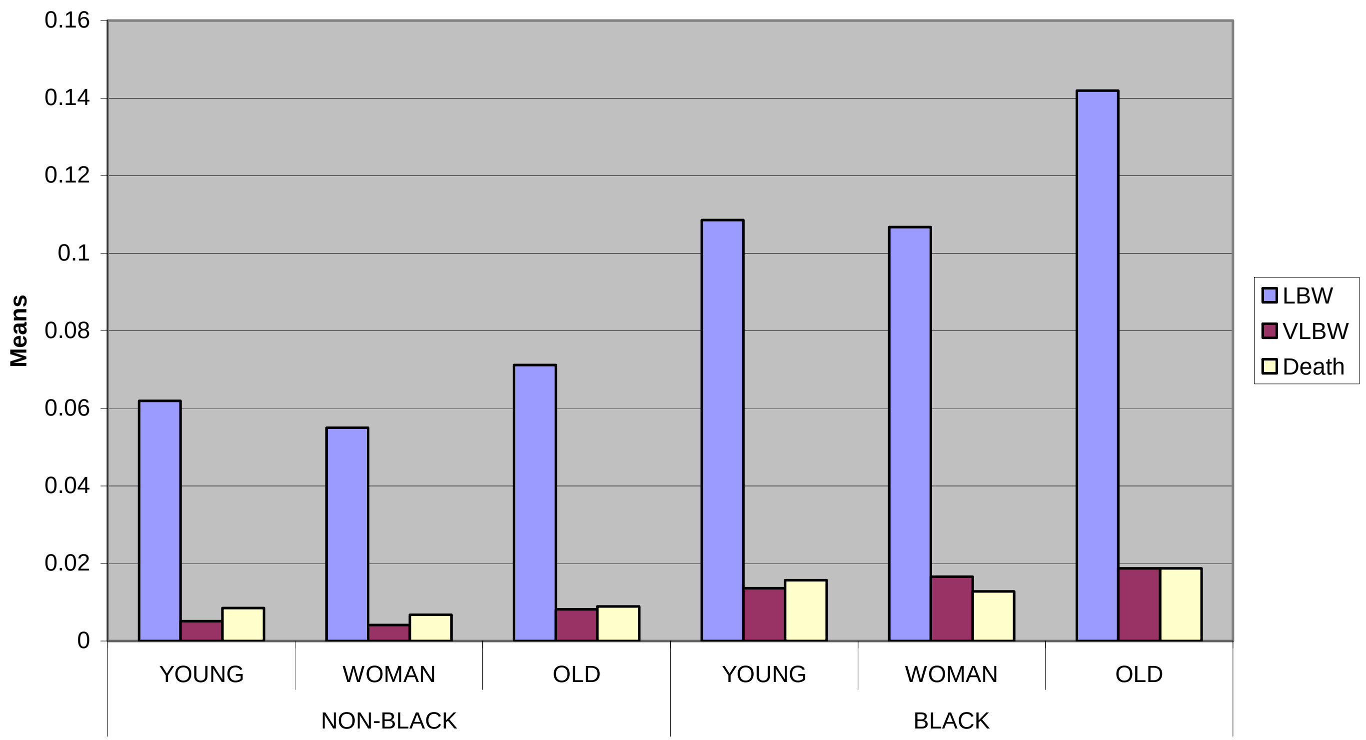


Chart 2: Prenatal Care Delay by Race and Birth Weight

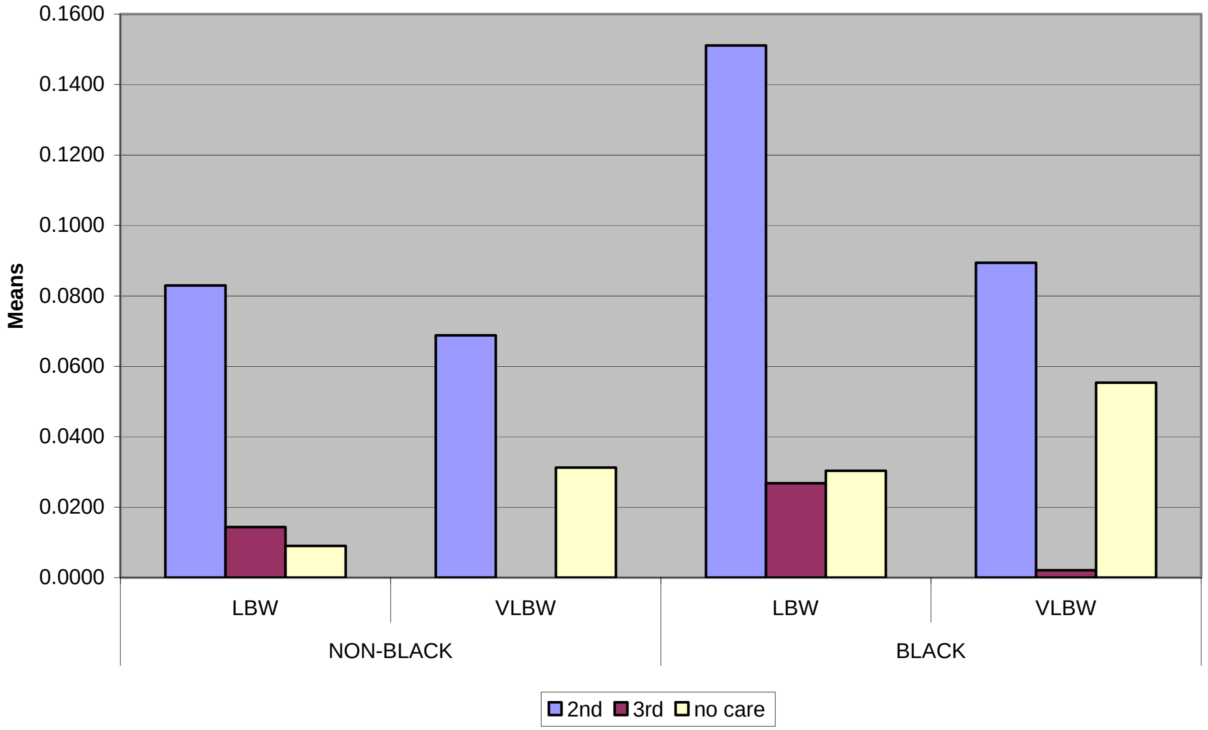
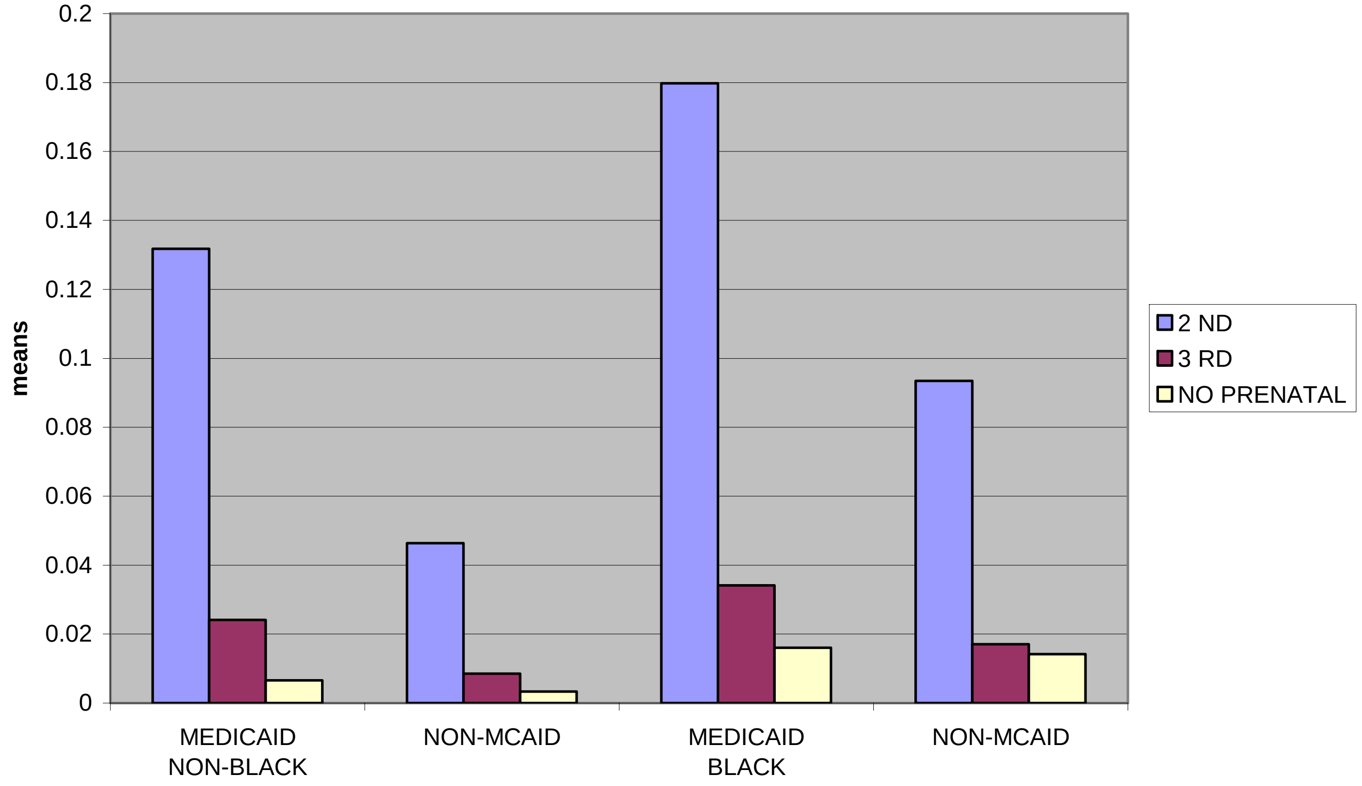


Chart 3: Prenatal Delay and Medicaid Status



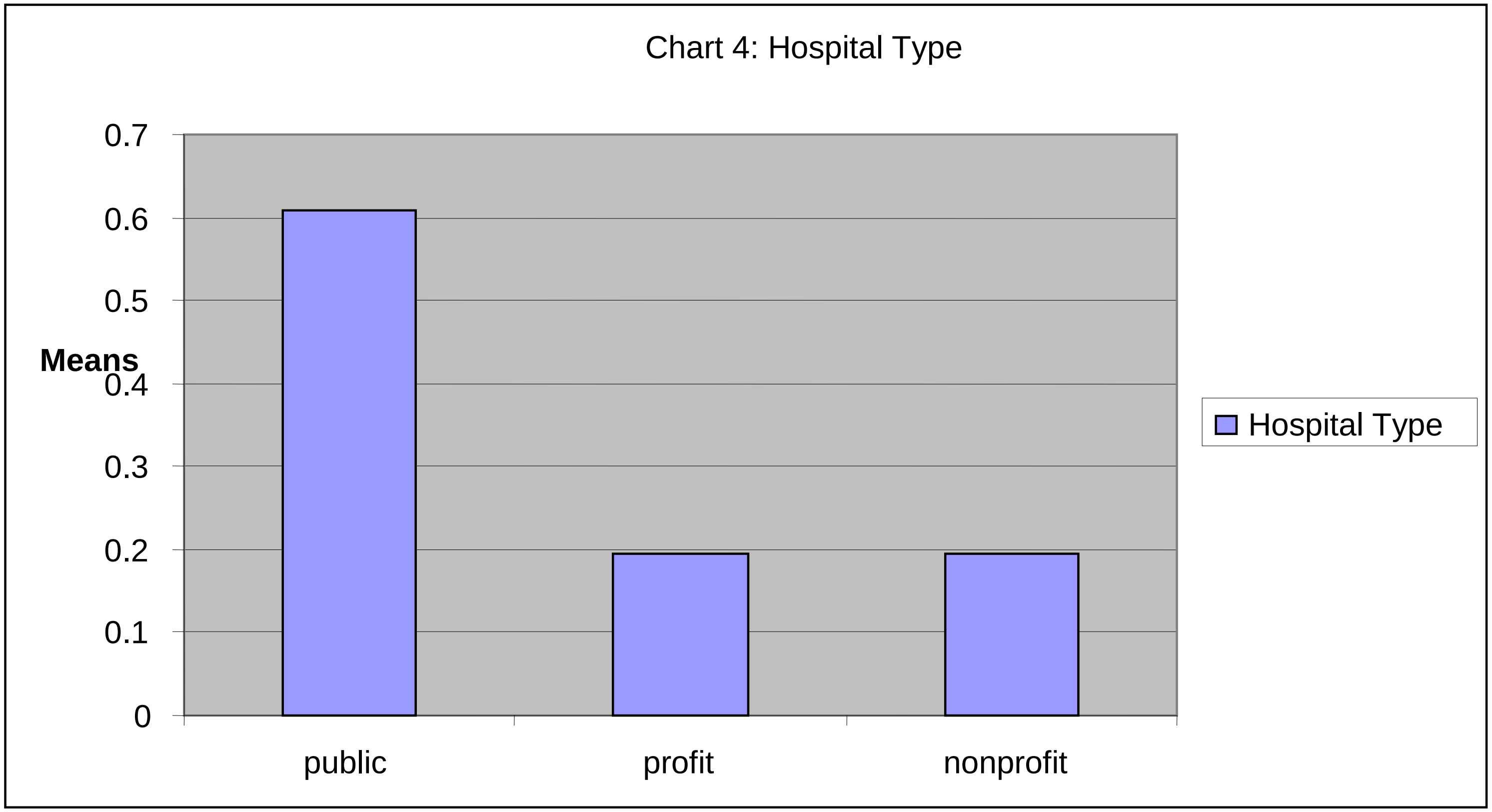
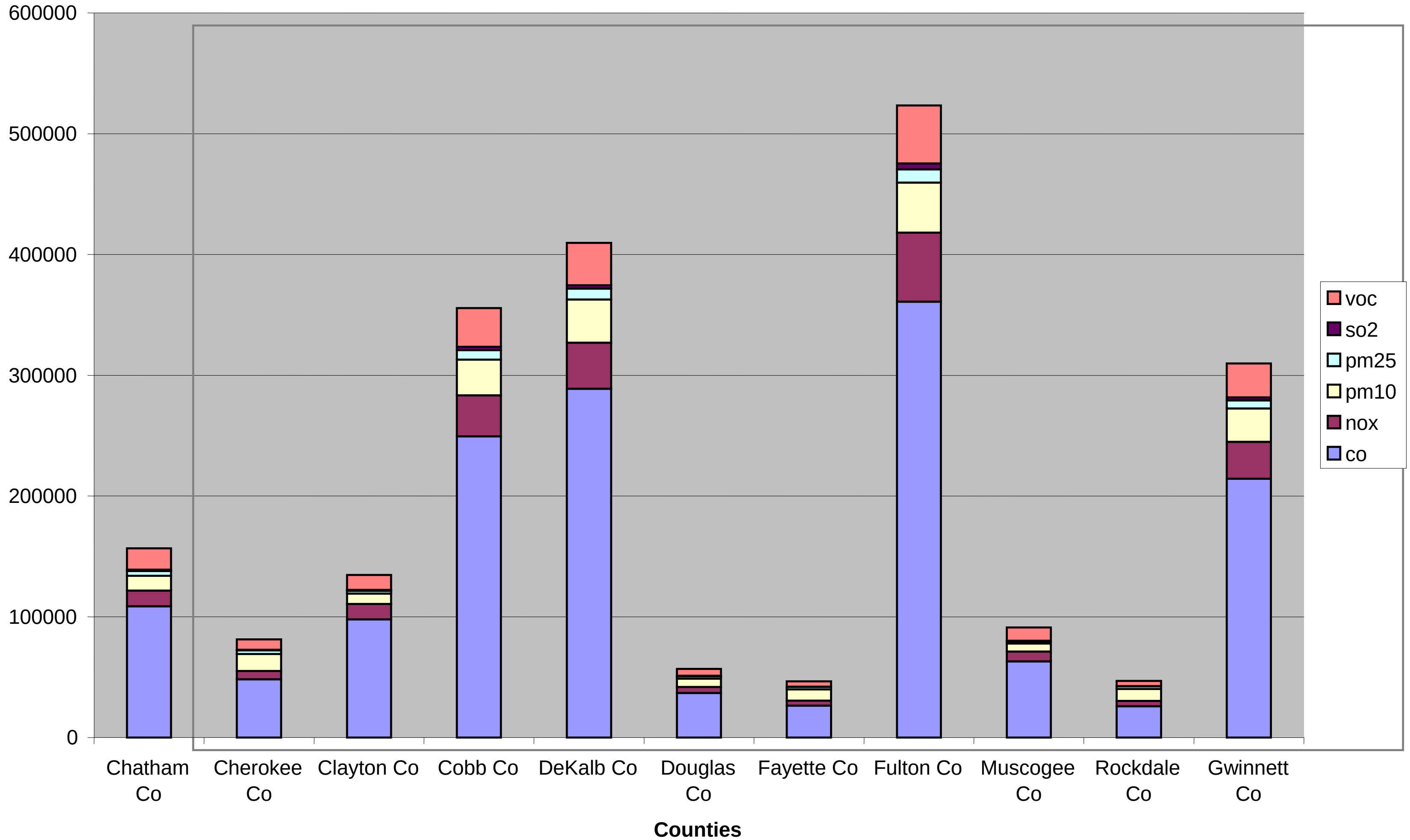


Chart 4: Hospital Type
Means
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
public
profit
nonprofit
Hospital Type

Chart 5: Air Pollution Levels



Appendix A:

List of PM2.5 Non-Attainment Counties in Georgia

1-Barrow
2-Bartow
3-Bibb
4-Carroll
5-Catoosa
6-Cherokee
7-Clayton
8-Cobb
9-Coweta
10-Dekalb
11-Douglas
12-Fayette
13-Floyd
14-Forsyth
15-Fulton
16-Gwinnett
17-Hall
18-Heard
19-Henry
20-Monroe
21-Newton
22-Paulding
23-Putnam
24-Rockdale
25-Spalding
26-Walker
27-Walton

Appendix B:

Medical Terms

Abruptio Placenta The parting of the placenta before birth, it could lead to heavy bleeding and to a cesarean.

Eclampsia The gravest form of pregnancy poisoning, cause is unknown. It increases the risk of hypertension and preterm birth.

Hydramnios Excess of fluid surrounding the fetus. It is associated with maternal diabetes and fetal anomalies.

Hypertension High blood pressure. It is one of the leading causes of maternal and infant morbidity and mortality. It can lead to cardiac and renal complications It is associated to intrauterine growth retardation.

Hemoglobin Carries oxygen to the cells from lungs and carbon monoxide away from cells to lungs.

Hemoglobinopathy Change in the structure of hemoglobin molecule (inherited diseases).

Methemoglobin Form of hemoglobin where iron compound is changed so that it cannot carry oxygen.

Placenta Previa When the placenta covers the cervix, it could lead to heavy bleeding if it is not pick up during prenatal visits.

APPENDIX C:

Table C.14: Prenatal and Prenatal Squared Equations from random sample

	Black				Non-black			
	PNC		PNC SQ		PNC		PNC SQ	
	$\hat{\beta}$	t	$\hat{\beta}$	t	$\hat{\beta}$	t	$\hat{\beta}$	t
Urban residence	0.0750	0.43	3.0172	0.75	0.1328	1.75	6.1581	2.93
young woman	-0.2397	-1.63	-4.6386	-1.38	-0.1486	-1.68	-4.1235	-1.64
old woman	-0.3234	-1.27	-5.4308	-0.94	0.0290	0.21	2.4045	0.62
less high school	-0.7011	-3.96	-11.9966	-3.29	-0.5385	-4.66	-11.1581	-3.55
some college	0.7117	4.82	13.8861	4	0.4405	4.92	8.9332	3.41
married	0.8045	4.83	16.7602	4.2	0.5977	4.73	14.6869	4.14
father's name missing	-1.2046	-8.17	-20.0169	-6.31	-0.7722	-4.12	-8.0343	-1.39
Medicaid	-0.3496	-0.92	-6.1381	-0.7	-0.2378	-1.25	-2.7252	-0.55
crime index	1.6794	0.57	-0.7760	-0.01	2.5150	1.27	43.2435	0.87
ratio person to doctor	0.1694	2.79	2.8491	2.11	0.0365	0.8	-0.2533	-0.21
population density	0.0015	3.5	0.0289	2.98	0.0005	1.73	0.0091	1.21
% black in zip code	-0.0013	-3.72	-0.0182	-2.2	-0.0012	-4.59	-0.0237	-3.11
Unemployment rate	1.0943	1.73	25.5474	1.63	0.2289	0.59	13.5711	1.25
% female head HH	-0.0674	-1.7	-1.2488	-1.56	-0.7761	-8.14	-17.7582	-7.66
Medicaid* FemaleHH	-2.9576	-0.84	-54.2014	-0.7	-5.8923	-2.95	-175.0863	-3.2
per capita income	0.3261	1.4	6.9263	1.38	-0.1009	-1.19	-1.1482	-0.52
constant	9.2700	9.68	98.7541	4.53	14.3347	21.66	212.7937	11.95

Table C.15: Birth Weight Equation from random sample

	Black						Non-black					
		Robust			Robust			Robust			Robust	
	$\hat{\beta}$	Std. Err.	t	$\hat{\beta}$	Std. Err.	t	$\hat{\beta}$	Std. Err.	t	$\hat{\beta}$	Std. Err.	t
	IV			FIXED			IV			FIXED		
Gestation	184.2501	4.0675	45.3	186.0855	4.2615	43.67	200.3015	5.4621	36.67	199.8891	5.6329	35.49
prenatal care	-238.3652	136.6791	-1.74	-396.8934	168.9212	-2.35	68.8264	40.0880	1.72	54.0383	42.8861	1.26
prenatal squared	13.2073	7.9857	1.65	22.7232	9.9368	2.29	-3.1983	1.9256	-1.66	-1.8800	2.1262	-0.88
weight gain	3.5976	0.5706	6.3	3.5089	0.5671	6.19	5.2948	0.4082	12.97	5.3339	0.4066	13.12
young woman	-11.0200	16.6026	-0.66	-0.7194	17.0084	-0.04	-19.1613	10.9961	-1.74	-17.4707	11.1484	-1.57
old woman	-20.4679	28.1166	-0.73	-19.5320	28.2390	-0.69	-15.4259	18.3627	-0.84	-18.5453	18.4256	-1.01
less high school	-45.4387	19.3056	-2.35	-42.8613	19.5283	-2.19	-21.3097	14.4972	-1.47	-12.4859	14.8673	-0.84
some college	24.9150	22.1717	1.12	5.2967	25.0185	0.21	16.8121	11.9174	1.41	10.4180	12.2667	0.85
married	5.0227	31.4208	0.16	-27.8789	36.8531	-0.76	67.8234	15.6563	4.33	57.3649	16.3510	3.51
female (sex of baby)	-108.0313	12.5307	-8.62	-108.6782	12.5311	-8.67	-123.4741	8.7942	-14.04	-123.9905	8.7907	-14.1
Medicaid	-22.6398	40.6917	-0.56	-24.5319	41.0370	-0.6	-49.9085	23.5550	-2.12	-46.7679	23.6904	-1.97
smoke	-100.8464	26.5413	-3.8	-98.6076	26.7322	-3.69	-200.1382	12.5197	-15.99	-200.5787	12.5747	-15.95
Diabetes	282.1981	53.8308	5.24	278.5915	54.3400	5.13	225.2550	36.5213	6.17	228.2102	36.8399	6.19
hydramnios	-182.5172	53.6479	-3.4	-182.0997	53.5705	-3.4	-136.3616	41.7917	-3.26	-132.6282	42.2830	-3.14
chronic hypertension	-128.5542	58.6832	-2.19	-110.6448	59.2195	-1.87	-136.2900	69.2194	-1.97	-146.7592	70.4572	-2.08
hypertension	-101.5929	39.1187	-2.6	-90.8966	38.7731	-2.34	-68.3371	24.2619	-2.82	-68.2619	24.3372	-2.8
Hypertension*diabetes	171.2362	224.5630	0.76	156.2073	225.4841	0.69	45.0653	265.6487	0.17	51.4683	266.3813	0.19
parity	25.8951	5.2503	4.93	26.5595	5.2535	5.06	33.2133	4.6603	7.13	33.3271	4.6580	7.15
population density	-0.0137	0.0537	-0.26	-0.0922	0.0663	-1.39	-0.0377	0.0226	-1.67	-0.0304	0.0285	-1.07
% black in zip code	-77.6822	76.0513	-1.02	-161.8936	87.9557	-1.84	11.1527	46.0516	0.24	-54.6548	52.9372	-1.03
% female head HH	87.3534	413.5713	0.21	266.7292	418.7265	0.64	-40.8821	283.5562	-0.14	111.1934	297.9804	0.37
Medicaid*FemaleHH	437.0498	394.9892	1.11	743.4821	424.1164	1.75	187.3848	250.4729	0.75	152.4867	252.5736	0.6
per capita income	-22.6030	23.6437	-0.96	-24.9252	25.4469	-0.98	10.9645	10.2912	1.07	1.7010	11.3615	0.15
warm season	-10.4347	12.5310	-0.83	-11.2917	12.6343	-0.89	9.6321	8.7251	1.1	8.7728	8.7368	1
part matter size10	-30.1912	29.9001	-1.01	4.8964	36.7314	0.13	-54.4358	16.4685	-3.31	-63.2359	21.4601	-2.95
Urban	-80.9623	35.9250	-2.25	-107.9529	40.9725	-2.63	-38.2633	23.2885	-1.64	-24.3280	23.9518	-1.02
Urban*PM10	15.6965	26.8108	0.59	24.2248	31.1313	0.78	56.4570	21.2881	2.65	34.4383	21.9961	1.57
non-attainment	1.3525	18.0893	0.07	-26.9345	27.9968	-0.96	13.7171	12.8855	1.06	8.9282	16.4014	0.54
profit	3.4119	24.2227	0.14	14.4734	24.8453	0.58	-8.0585	12.9548	-0.62	-6.5313	13.5032	-0.48

non-profit	19.2476	18.6599	1.03	15.0667	19.7837	0.76	2.2203	13.8106	0.16	-5.5582	14.6202	-0.38
Fayette Coweta Spalding				310.5092	196.9959	1.58				-196.8821	115.6131	-1.7
Paulding Bartow				89.6970	128.6529	0.7				-162.8804	93.7366	-1.74
Henry Rockdale				-84.6220	144.4894	-0.59				-229.2810	95.1445	-2.41
Lithonia				-11.3680	154.8593	-0.07				-372.6630	110.3834	-3.38
Marietta				136.6682	173.2302	0.79				-79.0439	123.6428	-0.64
Smyrna				-75.9018	199.0322	-0.38				-105.9233	198.6788	-0.53
Austell Mableton				-174.9929	142.7347	-1.23				260.8615	334.4479	0.78
Acworth Kennesaw				58.5749	161.4310	0.36				-169.6202	99.4468	-1.71
Forsyth hall				-212.6255	151.0212	-1.41				-190.5846	97.4487	-1.96
st mountain				301.1192	139.4786	2.16				95.7946	172.4546	0.56
Avondale				-214.1030	197.8934	-1.08				-288.1616	463.1984	-0.62
Doraville druid hill				99.4162	172.7315	0.58				-22.4074	145.1106	-0.15
Alpharetta										-291.0603	187.8202	-1.55
sandy spring										-391.1421	132.3794	-2.95
midtown				110.1254	135.5361	0.81				582.1674	188.9103	3.08
downtown				-13.6480	131.6880	-0.1				747.8147	103.6334	7.22
college park				63.4328	157.3438	0.4				58.9282	118.8653	0.5
Lilburn Norcross				391.5822	128.1739	3.06				30.7578	137.5607	0.22
Lawrenceville				-197.4411	440.9588	-0.45				-15.8548	129.9343	-0.12
Snellville				388.8006	165.1816	2.35				15.6467	214.5262	0.07
Duluth Suwannee				-162.2456	277.6434	-0.58				-42.4156	128.1719	-0.33
savannah				95.4581	121.9750	0.78				-156.6191	91.9796	-1.7
northeast				66.2503	134.4336	0.49				-186.6174	96.5537	-1.93
northwest				60.4669	132.0541	0.46				-183.5518	92.6006	-1.98
central				149.8452	125.5880	1.19				-143.4142	90.9578	-1.58
southwest				179.5119	128.7785	1.39				-114.5077	94.5746	-1.21
south				153.7667	137.7381	1.12				-194.5275	101.9658	-1.91
constant	-3102.511	476.4325	-6.51	-2804.181	554.4009	-5.06	-4860.347	284.3285	-17.09	-4672.4980	286.1833	-16.33
	N= 4363						N = 9759					
	R^2 = 0.730			R^2 = 0.732 F (25, 4310) = 3.28			R^2 = 0.582			R^2 = 0.584 F (27, 9704) = 16.36		
				Prob > F = 0.0000						Prob > F = 0.0000		

Table C.16: Probit Results from full sample

	Black			Non-black		
	$\hat{\beta}$	Robust Std. Err.	z	$\hat{\beta}$	Robust Std. Err.	z
predicted weight	-0.0004	0.0000	-12.62	-0.0004	0.0000	-14.6
urban residence	-0.0015	0.0946	-0.02	-0.0136	0.0678	-0.2
young woman	0.0718	0.0527	1.36	0.0160	0.0469	0.34
old woman	0.0931	0.0801	1.16	0.0433	0.0610	0.71
less high school	-0.0146	0.0612	-0.24	-0.0152	0.0582	-0.26
some college	-0.1280	0.0550	-2.33	-0.0125	0.0472	-0.26
married	0.0065	0.0599	0.11	-0.1477	0.0608	-2.43
father's name missing	-0.0078	0.0528	-0.15	-0.0807	0.0792	-1.02
female (sex of baby)	-0.0767	0.0448	-1.71	-0.0872	0.0384	-2.27
Medicaid	0.3163	0.1279	2.47	-0.1297	0.1083	-1.2
smoke	-0.0802	0.1042	-0.77	0.0529	0.0550	0.96
drink	-0.2112	0.2063	-1.02	-0.5277	0.2321	-2.27
Heart problems	0.2344	0.2792	0.84	0.3531	0.2590	1.36
Lung problems	0.6285	0.1207	5.21	0.3450	0.4405	0.78
Hypertension*diabetes	0.2090	0.0746	2.8	0.9537	0.0812	11.75
Congenital anomalies	1.7775	0.1180	15.06	0.0843	0.0698	1.21
Abnormal conditions at birth	0.4023	0.0784	5.13	1.9494	0.1167	16.7
Bad apgar score	0.0000	0.0001	-0.35	0.7123	0.0691	10.31
Moderate apgar score	0.0132	0.0128	1.03	0.0000	0.0001	-0.2
percent county beds	0.0002	0.0001	2.91	0.0160	0.0277	0.58
unemployment rate	1.4471	1.3003	1.11	0.0000	0.0001	0.67
population density	-0.2303	0.1612	-1.43	1.5624	1.5993	0.98
percent pop public asst	2.9964	1.1707	2.56	0.1280	0.2167	0.59
% black in zip code	-2.5625	0.9001	-2.85	-1.6304	1.3311	-1.22
% female head HH	0.0790	0.0610	1.3	0.6749	1.1748	0.57
Medicaid* FemaleHH	0.0355	0.0446	0.8	-0.0444	0.0365	-1.21
per capita income	-0.0422	0.0478	-0.88	0.0382	0.0381	1
warm season	0.0123	0.0388	0.32	0.0229	0.0308	0.75
particulate matter size10	-0.0794	0.0818	-0.97	-0.0422	0.0271	-1.56
Urban*PM10	0.0131	0.0722	0.18	-0.0407	0.0597	-0.68
Non-attainment county	0.0372	0.0651	0.57	0.0058	0.0593	0.1
profit	-1.8024	0.2580	-6.99	-0.0110	0.0588	-0.19
Non-profit	-0.0004	0.0000	-12.62	-0.9447	0.2015	-4.69
constant	-0.0015	0.0946	-0.02	-0.0004	0.0000	-14.6
	N = 29104			N =63378		
	LOG LIKELIHOOD = -1624.43			LOG LIKELIHOOD = -2147.26		
	MFX at mean = 0.0078			MFX at mean = 0.0041		

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