University of South Florida
Scholar Commons

Graduate Theses and Dissertations | Graduate School

2004

A multilevel modeling analysis of the geographic variability of low birth weight occurrence in Florida

Joseph William Green
University of South Florida

Follow this and additional works at: http://scholarcommons.usf.edu/etd

Part of the American Studies Commons

Scholar Commons Citation

Green, Joseph William, "A multilevel modeling analysis of the geographic variability of low birth weight occurrence in Florida" (2004). *Graduate Theses and Dissertations.*
http://scholarcommons.usf.edu/etd/1054

This Thesis is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.

A Multilevel Modeling Analysis of the Geographic Variability of Low Birth Weight Occurrence in Florida

by

Joseph William Green Jr.

A thesis submitted in partial fulfillment
of the requirement for the degree of
Master of Arts
Department of Geography
College of Arts and Sciences
University of South Florida

Major Professor: Steven Reader, Ph.D.
Graham A. Tobin, Ph.D.
Thomas J. Mason, Ph.D.

Date of Approval:
October 14, 2004

Keywords: low birth weight, multilevel modeling, deprivation, medical geography

© Copyright 2004, Joseph William Green Jr.

Dedication

This thesis is dedicated to Joseph William Green Sr. and Bonita Marie Green.

Acknowledgements

I would like to express my most sincere gratitude to the many individuals who have assisted me during my quest to produce this thesis. In particular, I would like to thank Dr. Steven Reader for his guidance, support and encouragement. A sincere thank you also goes to my committee members, Dr. Graham Tobin and Dr. Thomas Mason for their contributions and support.

A special thank you is given to my family for their patience, love and continual support and encouragement. I could not have done it without you; thank you Mom, Dad, and Lara.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

A Multilevel Modeling Analysis of the Geographic Variability of Low Birth Weight Occurrence in Florida

Joseph William Green Jr.

ABSTRACT

The associations of neighborhood level socioeconomic deprivation and low birth weight were investigated among 1,030,443 singleton live births in the State of Florida between the years 1992 and 1997. Census data for per capita income, unemployment, percent of individuals living below the poverty line, vehicle ownership and educational attainment were used as neighborhood level indicators of socioeconomic status. Additionally, these variables were combined into a deprivation index to measure relative deprivation of neighborhoods across Florida. Birth data were linked to census block groups and tracts, which were used as proxies for low birth weight. Multilevel models were used to model the relationship between the deprivation index and each of the indicators and low birth weight, while adjusting for individual level risk factors. After adjusting for individual level factors no consistent relationship between neighborhood socioeconomic measures and low birth weight could be established. The relationship between neighborhood socioeconomic factors and low birth weight varied across ethnic categories. Among White Non-Hispanics and Hispanics measures of socioeconomic deprivation had a small association with low birth weight. However, for Black Non-Hispanics neighborhood measures had little consistency in predicting the occurrence of low birth weight

CHAPTER ONE:

INTRODUCTION

Introduction

This study uses a multilevel analysis model to study the simultaneous effects of individual level variables and group-level characteristics on low birth weight outcomes. The purpose of this exercise is twofold. First, it is a way to further explore and conceptualize the relationship that exists between characteristics of geographic location and low birth weight incidence. Second, it is an investigation of the usefulness of multilevel analysis in predicting and explaining the variability seen in health outcomes. Additionally, this study brings a geographic perspective to a public health issue in the hopes of further understanding the relationship between place of residence and health outcomes.

Low birth weight outcomes were used as the dependent variable in this multilevel analysis. Low birth weight is one of the most studied outcomes in public health, in part due to the ready availability of data through vital statistics (Wilcox 2001). It remains a serious public health issue to this day. A low weight at birth is associated with an increased risk of mortality during the first year of life and an increased risk of chronic diseases in adulthood, negative developmental and health outcomes (Klein et al. 1989;

Hack 1994; Shino and Berhman 1995; Harding 2001; Terry and Susser, 2001). The majority of available studies focus on individual level variables like maternal nutrition for example. Other studies have attempted to examine ecological factors in attempts to determine the contextual influences and spatial variability of low birth weight incidence. (Kieffer et al. 1993; Shiono and Behrman 1995; Cross et al. 1997; Reader 2001). Each approach contributes to the understanding of the variables influencing low birth weight, but limitations do exist with both an individual and an ecological (or group-level) analysis, which may be overcome through the proper use of a multilevel analysis.

Traditional multiple regression models attempt to estimate a relationship between an outcome (response or dependent variable) and one or more independent variables (predictor variables). A multiple regression model will show an average relationship between the response and predictor variables assuming that residuals are independent. However, the multilevel structure of some data violates this assumption. Such a violation can commonly be seen in hierarchal or nested data (TRAMSS 1999). The social context or geographic place of residence of an expectant mother is one such example. Therefore, this paper approaches the issue of low birth weight as a multilevel data hierarchy. With mothers and their individual-level risk factors nested within geographic areas of study. The geographic areas of study are census block groups, which are used as proxies for neighborhoods.

CHAPTER TWO:

LITERATURE REVIEW

Defining Low Birth Weight

Arvo Ylppo defined the threshold weight for low birth weight (LBW) as a birth weight of <2500 g. This value has continued to be used in the literature to this day. The purpose of this definition was originally to differentiate between infants carried to full term and those born pre-term. At the time of this definition, birth weight and gestational age were used interchangeably. It was assumed that babies born with a LBW were premature. Because of this assumption the definition of prematurity was considered to be LBW. This definition persisted in the literature through the 1960's. (Kiely et al.1994)

In the late 1940's, starting with McKewan and Gibson (1947), and continuing through the 1960's, epidemiological evidence began to accumulate which would clearly define the differences between low birth weight and gestational age. It became clear that not all low birth weight babies were premature. Additionally, some premature babies were not of low birth weight. Researchers began to recognize that (LBW) babies could be placed into two groups; babies born preterm (earlier than 37 weeks gestation) and those carried full term but which exhibited intrauterine growth retardation (IUGR). In 1961 the World Health Organization (WHO) formally recommended against the use of LBW as the definition for prematurity. Not long after the WHO's recommendation, the use of the term *premature* was abandoned in favor of the more descriptive term *preterm*. (Kiely et al. 1994)

The definition of LBW itself has not changed. However, it now only denotes the weight at birth of an infant. No longer does it carry the assumptions about gestational age. It may be instructive to differentiate between IUGR and preterm birth when discussing low birth weight when attempting to investigate or explain potential causes of LBW associated with full term infants of low birth weight. However, for the purposes of this study the outcome of interest is low birth weight, which will include low birth weight babies of normal gestational age and those born preterm.

Trends

The LBW rate in the United States was 7.7% in 2001. This is an increase from the 2000 rate of 7.6%. The LBW rate for 2001 was the highest recorded since 1970 (7.9%). The LBW rate decreased in 1985 to 6.75% and has risen to current levels. The percent of very low birth weight (VLBW) (birth weight less than 1500 g) births was 1.4%, which is up from 1.27% in 1990 but less than the highest rate of 1.67 in 1981 (NCHS 2001)

Racial Differences in Birth Weight Trends

The LBW rate among non-Hispanic whites has steadily increased from 5.6% in 1990 to 6.8% in 2001. While the LBW rate among non-Hispanic blacks decreased from 13.6% in 1990 to 13.1% in 2001. Despite this trend non-Hispanic black mothers remain approximately twice as likely to have a LBW baby as a non-Hispanic white mother. The

LBW rate among Hispanic mothers increased from 6.1% in 1990 to 6.5% in 2001. The aforementioned numbers include both singleton and multiple births. Infants born of multiple births are 10 times as likely as a singleton to be of low birth weight. Therefore, the increases seen in non-Hispanic white births are partially due to the increased rate of multiple births (NCHS 2001). Regardless, singleton births among the various racial categories show similar trends (see Table 2.1).

Table 2.1 Low Birth Weight Rate by Race and Hispanic Origin of Mother (Singleton Births) (NCHS 2001)

	2001	2000	1995	1990
Non-Hispanic White Percent Low Birth Weight	5.77	5.68	5.65	5.29
Non-Hispanic Black Percent Low Birth Weight	13.76	13.9	14.15	14.46
Hispanic Percent Low Birth Weight	6.33	6.3	6.29	6.1

Public Health Implications of Low Birth Weight

While most children born with low birth weight develop no significant health problems, low birth weight babies, as a whole, are more likely to have abnormal growth and development as well as adverse health conditions (Hack et al. 1994). Numerous studies implicate low birth weight as a predictor for cardiovascular disease in adulthood (Barker 1992; Kuh and Ben-Shlomo 1997; Terry and Susser 2001; Harding 2001). Low birth weight has been implicated in numerous prospective cohort studies as a predictor for other diseases as well (Type II diabetes, breast and other cancers). Infants born with low birth weight are more likely to have brain injuries, lung and liver disease. Children born of low birth weight are at an increased likelihood of having learning disabilities, attention deficit disorders, breathing problems and developmental impairments. (Hack et al. 1994) Reports in developed as well as developing countries support these findings (Terry and Susser 2001).

Risk Factors for Low Birth Weight

The majority (70%) of low birth weight babies are born pre-term (before 37 weeks) (Kieley et al. 1994). There are numerous risk factors for pre-term births, which include; carrying more than once baby, a history of pre-term births, exposure to tobacco smoke, environmental stressors, bladder or vaginal infections during pregnancy, or previous abortions. Numerous studies have supported the associations between these risk factors and low birth weight. Kiely et al. (1994) discuss the findings and limitations of many of these studies. Moreover, they have divided the risk factors as follows:

Demographic Risk Factors

- Maternal Age
- Race and Ethnicity
- Marital Status
- Socioeconomic Status

Toxic Exposures Risk Factors

- Cigarette Smoking
- Alcohol Consumption
- Illicit Drug Use
- Ambient Environmental Exposures

Pregnancy Risk Factors

- Maternal Height and Weight
- Reproductive History
- Weight Gain During Pregnancy
- Prenatal Care
- Parity of 0 or >5

Medical Risks

- Hypotension
- Hypertesion/preeclampsia/toxemia
- Genitourinary abnormalities/surgery
- Poor obstetric history
- Maternal genetic factors
- Infections (including rubella, bacteriuria and cytomegalovirus)

When examining the possible interaction between individual-level characteristics (e.g., maternal health, smoking etc.) and the group-level characteristics (e.g., neighborhood and socio-economic status) it becomes clear that the level of analysis must reflect the interplay between the individual and the group. Multilevel analysis may be a useful tool in examining such interactions.

Theoretical Conceptualization of Levels of Analysis in Health Research

The investigations of health outcomes have traditionally been divided into two distinct levels of analysis; ecologic (aggregate studies) and individual-level studies (Greenland 2001). Ecologic studies focus on group-level analysis in which the basic unit of analysis is the population. A study that seeks to link average income to mortality rate due to cardiovascular disease would be one example of an ecological study. Ecological studies in this context are generally descriptive and hypothesis-generating. Rarely, should such studies be used for the testing of hypotheses (Szklo and Nieto 2000). Such an analysis is generally reserved for the individual-level analysis. Individual-level studies, like cohort and case control studies, are often used with the underlying idea that disease determinants are best studied at the individual-level (Diez-Roux 2000). Individual level analysis is considered the "gold-standard" in epidemiologic studies and as such, ecologic studies are often considered to be a poor surrogate for individual-level analysis. This is due, in part, to the assumption that individual-level outcomes are best explained by individual-level independent variables (Diez-Roux 2000; Szklo and Nieto 2000). Neither the ecologic, nor the individual-level studies take into account the interaction between the aforementioned levels of analysis simultaneously. Rather, they break the analysis down to a common level and ignore the interactions between the two levels. This is largely due to the desire to avoid the ecological bias that can arise from making population based inferences about individual level outcomes, this is know as the ecological fallacy. It is also possible to draw faulty inferences in the opposite direction, when inferences are made about population level outcomes from individual level data; this is known as the atomistic fallacy. Traditional studies of health outcomes generally ignore the individual's interaction with social factors or groups of which they are a part. This is a problem because determinates of disease and health alike operate in a larger social context, not just at the individual level (Hox 1995; Diez-Roux 2000; Greenland 2001).

As discussed previously there are two levels of analysis from which an investigator traditionally would work from. There are however several ways that a study can be theorized. Diez-Roux (2000) breaks down four basic design theories. It is imperative to understand how best to apply one of the following theories before proceeding with an analysis, multilevel or otherwise. The first way, and most commonly practiced in the epidemiologic literature, would be to explain an observed outcome at one level with independent variables at the same level. The second way would be to explain an ecologic-level outcome with individual-level independent variables. However, this could, if not properly conceptualized, lead to an atomistic fallacy. The third way would be to explain an individual-level outcome with an ecologic-level independent variable, although, this would most likely lead to some form of ecological fallacy. The fourth way a study could be theorized involves the explanation of an outcome at one level based on variables at various levels as well as interactions between levels. Multilevel analysis can best be used in the latter type of analysis.

Why have studies of health generally stayed to one level of analysis or another? An historical examination of the causal explanations of disease may prove illustrative. As outlined in Courgeau (2003) (see also Cassel 1964, Diez-Roux 2003; Pearce 1996; Susser and Susser 1996 for a more complete discussion of eras and paradigms in epidemiology) epidemiology has seen several distinct paradigm shifts regarding the explanation of the causal mechanisms of disease. It is useful to note the shifting paradigms seen in epidemiology closely parallel the theory of paradigm shifts developed by Thomas Kuhn in *The Structure of Scientific Revolutions* (1962). Kuhn (1962) notes that a hallmark of all mature scientific endeavors is the acceptance of one paradigm, which may last for long periods of time followed by the shifting to a new paradigm, generally caused by a new discovery. Moreover, new paradigms develop to answer questions that could not be addressed by the previous paradigm. However, the new paradigms should not be seen as the answer to all questions. This is what the history of epidemiologic inquiry closely resembles when examined historically.

The miasmatic theory of disease causation, formalized by Lancisi (1717), was the prevalent paradigm from antiquity through the 19th century (Courgeau 2003). In this paradigm of disease causation, unseen environmental factors were the culprits of disease. More specifically, diseases were caused when the soil, air or water was “bad” due to the decay of organic matter. This explanation of disease causation focused on the aggregate level of analysis. Sanitary conditions of populations were studied and related to disease outcomes in hopes of preventing the spread of disease.

The miasmatic theory of disease causation was eventually replaced by the germ theory of disease causation. The impetus for the paradigm change was spurred by advances in microbiology, especially Pasteur’s discoveries. Epidemiologists focused more on discovering disease causing agents and less on the environment and aggregate-level studies. This paradigm persisted until the middle of the twentieth century (Courgeau 2003; Diez-Roux 2003).

Although the germ theory of disease was instrumental in eradicating several diseases through the development of vaccines, chronic disease began to occupy the focus of scientists. Thus, began the chronic disease or risk factor paradigm, which focused on individual level variables and study designs. The majority of studies conducted in this manner focus on biomedical and behavioral factors and their interactions (all individual-level). This has often been referred to as the web of causation or multi-causal model of epidemiology (Diez Roux 2003).

The chronic disease model of causation is being reconceptualized by a growing number of epidemiologic researchers (Diez-Roux 2003; 2001; 2000). This is not because of its lack of efficacy; it is seen as an incomplete explanation of the causes of disease, especially chronic disease. The new paradigm should assimilate all of the previous paradigms along with a new approach, one that also takes the social context of disease into account. The current discussion and formulation of this new paradigm focuses on how best to conceptualize the social context of disease (WHO 1998; Diez-Roux 2000; Diez-Roux 2001; Diez-Roux 2003) Or, to put it another way, how can factors like social context be included in the analysis of disease causation.

Another reason for the focus on one level of analysis at the expense of others is the largely positivistic nature of epidemiologic research and to some extent medical geography. This is due in large part to the study of the diseases themselves. As illustrated previously the diseases and the humans with the disease of study were treated to some extent as automata with a definite cause and effect relationship. This is not entirely incorrect, however it must be realized that humans are social beings within a larger context. By removing the focus from the solely empirical nature of past research a broader understanding of health outcomes and their context may be gained.

The social sciences have long recognized the interaction between individuals and their surroundings. It is a central component to many disciplines within the social sciences. Glidden's' structuration theory and the critical realist ideology are two examples of theoretical frameworks from the social sciences which place an individual within a broader context and account for the multilevel nature of simultaneous individual and group level interaction. (Duncan et al. 1996) Glidden's' structuration theory highlights the interplay between individuals and social structure, which will eventually produce certain socio-cultural structures and contexts as well as manifestations of social behavior. (Giddens 1984) Critical realism rejects the notion that explanations of phenomena are transhistorical and transcultural. Rather, they are place and time specific and as such are contextually influenced. (Duncan et al. 1996; Bhaskar 1975) A robust theoretical framework combining Giddens' structuration theory and a critique from the realist perspective would further aid in the clarification and conceptualization of contextual health effects. Once the context is fully and accurately theorized for then the quantitative analysis of the relationship between the individual and context can be undertaken.

While qualitative theories as to the nature of individual-context interaction are part of the solution to including context in public health research a, quantitative approach is still necessary. This led to the development of multilevel analysis (Blalock HM 1984; Diez-Roux 2000; Hox 2002.)

Multilevel Analysis

Multilevel analysis is a statistical methodology that is commonly used on data with a hierarchical structure (Hox 1995; Sullivan et al. 1999; Diez-Roux 2000). A hierarchical data structure contains a sequence of variables that contain or are contained by one another. For example, a simple two level hierarchical data structure would contain individual level variables nested within a group level variable. Individual level variables are characteristics of an individual such as age, sex or race. Group level variables are characteristics of a particular group that individual may belong to and may influence individual level outcomes for those individuals. The most common example given in multilevel literature is academic performance of children in different classrooms (Hox 1995). In this example, the characteristics of the individual children are the individual level variables. Those children are contained in classrooms the groups, to which the children are members. The purpose of conducting a multilevel analysis is to account for individual- and group-level effects on an individual-level outcome simultaneously. Multilevel analysis attempts to show how the context and contextual variability of an individual will affect the outcome under study (Diez-Roux 2000). This type of analysis can be easily applied to a geographic analysis, where individuals are nested within a particular geo-political unit, or even health research where individuals are nested within a larger socio-demographic unit (Hox 1995; Duncan et al. 1996; Diez-Roux 2000; Greenland 2000).

As stated previously multilevel analysis was originally developed as a way to model student performance in school and classroom settings (Hox 1995), it has since been used to address a number of health related outcomes in both public health and epidemiology, with admittedly mixed results. The first use of multilevel analysis in a public health context was by Wong and Mason (1985) and was further refined in Entwisle et al. (1986). These studies investigated how country and individual level variables affect an individual's fertility and contraception use. Logistic multilevel regression models were used to model World Fertility Survey data. These studies found that micro-level and, to a much lesser degree, macro-level socioeconomic factors effected contraception use. The subsequent usage of multilevel analysis in public health and epidemiology can generally be divided into several categories; health services research, alcohol and drug abuse research and geographic and social determinants of health.

Health services research is concerned with the availability and utilization of health services as well as the influence hospital and health care provider characteristics have on health outcomes and patient satisfaction. Multilevel analysis has been used extensively in this area of research to gauge the performance of various types of health services (Duncan et al. 1997; Entwisle et al. 1997; Duncan et al. 1999; Plote and Tager 2002; Merlo et al. 2001; Merlo et al. 2003). Analysis of health services appears to be a logical area for the application of a multilevel analysis. By its very nature health care service data are hierarchical. Individual patients are nested within hospitals or care providers. Moreover, individual level factors may interact with group level factors to influence utilization of health care services. In an example of one such study, Entwisle et al. (1997) used a multilevel analysis to address how accessibility to family planning services affects contraceptive choice in Nang Rong, Thailand. They found that travel time, road composition, relevance of alternative choices and local history of services were all influences on contraceptive choice.

Merlo et al. 2001 utilized a logistic multilevel regression to analyze the interaction between individual level and institutional level effect on heart failure outcomes in 90 hospitals in Sweden. The study focused on the variation in short-term prognosis (30 day mortality) following a hospital stay for heart failure that appeared to exist between different hospitals in Sweden. The results of their multilevel analysis showed that individual factors played a much greater role than contextual effects.

Merlo et al. 2003 used multilevel analysis to address potential contextual effect of neighborhood of residence on an individual's use of hormone replacement therapy (HRT) and anti hypertensive medication (AHM). This study is an example of the current trend in multilevel analysis, in which the effects of small geographic areas on individual level outcomes are examined. The findings of this study were mixed with regard to the effect neighborhood has on use of the therapies. No neighborhood effects were found for the use of AHM while women living in neighborhoods with low social participation were less likely to utilize HRT.

Studies of drug and alcohol abuse also use multilevel analysis to examine the characteristics of various contexts such as family or peer groups and their interaction with individual level factors (Reijneveld 1998; Wang et al. 1998; Rountree and Clayton 1999). For example, Wang et al. (1998) used a multilevel analysis to examine the influence of social context on the sharing of needles among intravenous drug users (IDU). They found that risk behaviors such as sharing needles are associated with individual characteristics as well as the social context IDUs are nested within.

The bulk of recent studies utilizing a multilevel analysis address the social determinants of health (Duncan et al. 1996; Sundquist et al. 1999; Diez-Roux 1999; Diez-Roux et al.

2001; Pearl et al. 2001; Rauh et al. 2001; Ahern 2002) Such studies focus on the interaction of physical, social and psychological environments and individual level risk factors in hopes of better understanding chronic disease outcomes.

Studies of social determinants of disease generally focus on some form of spatial inequity, usually socioeconomic status. In the majority of such studies the neighborhood of residence or some larger geographic area is used as the context-level variable. Neighborhoods vary in their socioeconomic environment. Much research is currently being focused on the role this may have in influencing an individual's health. For example, Raugh et al. (2001) utilized a logistic multilevel regression analysis to determine the effects maternal age, race and poverty had on low birth weight outcomes. They found that community poverty had a significant effect on low birth weight outcomes in New York City.

Diez-Roux et al. (2001) examined the influence of neighborhood of residence on the incidence of coronary heart disease when controlling for individual level factors. This study compared several neighborhoods in the US using data from the Atherosclerosis Risk in Communities Study. They used census block groups as a proxy for neighborhoods. Their findings showed that living in a disadvantaged neighborhood (independent of individual risk factors) is associated with and increased incidence of coronary heart disease.

An explanation of the variables of interest for a multilevel analysis can be found in Larzfeld and Menzel (1961), Swanborn (1981) and Hox (1995). Variables are conceptualized in the following way by Hox (1995) (figure 2.1):

Figure 2.1 Topology of Multilevel Variables (Hox 1995)

Note: Aggregations of data at a higher level are denoted with a →, while disaggregations are denoted with a ← symbol.

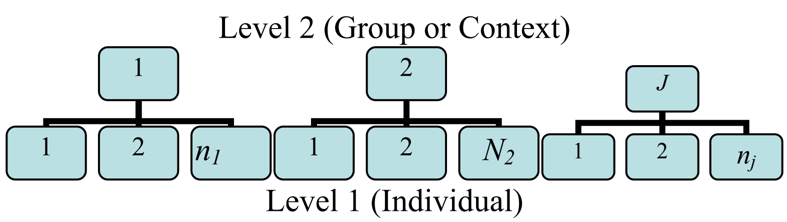
1st Level		2nd Level		3rd Level		Nth Level…
absolute	→	analytical				
relational	→	structural				
contextual	←	global	→	analytical		
		relational	→	structural		
		contextual	←	global	→	
				relational	→	
				contextual	←	

Hox (1995) explains the variables as follows: First-level variables are nested inside second-level and first and second-level are nested inside third level and so on. Within each level there are several types of variables. Absolute and global variables are variables that refer to the particular level of definition. Absolute variables are variables that are only unique to the individual. Relational variables describe the relationship of the units in one level to one another. Analytical variables refer to the distribution of an absolute or global variable at a lower level. Structural variables account for the distribution of relational variables at a lower level. Contextual variables account for the higher-level context within which, the lower level variables are located.

Explanation of Multilevel Model

Before summarizing the multilevel model it is important to be able to conceptualize the hierarchical data structure of the variables contained within the model. The notation developed by Bryk and Raudenbush (1992) for two and three level hierarchical data has been used in several other publications explaining multilevel analysis (Gatsonis et al. 1995 Sullivan et al. 1999; Diez-Roux 2000). The notation contained in both papers is both straight forward and easily carried over in a multilevel model. Therefore, to adhere to convention and utility, it is the same notation used here. For a two level hierarchical data structure, individuals comprise the first level (Level 1). Individuals are part of, or nested in groups or contexts (Level 2). At level 2 or the group level there can be J number of units or groups. Within level two there can be n_j individuals in each of the level two groups. This relationship is graphically represented in figure 2.2.

Figure 2.2 (From Sullivan et al. 1999) Hierarchical Data Structure



Explanation of the Statistical Model Based on a Two-Stage Simple Regression Model.

In a two-level hierarchical structure, such as the one illustrated in figure 2.2 with a continuous dependent variable, a two stage model is constructed with an individual-level

(level 1) regression model constructed for each group (contained in level 2) and a group level (level 2) model for each of the appropriate group-level covariates (Diez-Roux 2000 and Sullivan et al. 1999).

The first stage of a multilevel analysis is:

$$Y_{ij} = b_{0j} + b_{1j} I_{ij} + \varepsilon_{ij}$$

In the above equation Y_{ij} is the outcome variable or dependent variable for the *i*th individual unit nested within the *j*th group (in level 2). The next term, b_{0j}, is the intercept for the *j*th unit in the group-level (level 2). b_{1j} is the regression coefficient associated with the individual level variable I_{ij}, which is the level 1 covariate of the *i*th individual in the *j*th group. The symbol ε_{ij} is the random error for the individual-level (level 1) associated with the *i*th individual-level (level 1) unit nested within the *j*th group (level 2). Individual level errors are assumed to be normally distributed with a mean of 0 and a variance of σ^2.

The second stage equations of a multilevel analysis focus on the groups (level 2) as the unit of analysis. In this stage each of the group- or context- specific regression coefficients (b_{0j} *and* b_{1j}) are considered to be dependent variables and are modeled as a function of group level variables. Further explanation of variables can be seen in table 2.4 and 2.5.

$$b_{0j} = \gamma_{00} + \gamma_{01} C_j + U_{oj} \qquad U_{oj} \sim N(0, \tau_{00})$$

$$b_{1j} = \gamma_{10} + \gamma_{11} C_j + U_{1j} \qquad U_{1j} \sim N(0, \tau_{11})$$

Table 2.2 Explanation of First stage individual-level equation (from Diez-Roux 2001)

Equation Term	*Explanation*	*Assumptions*
Y_{ij}	*Outcome variable for i individual nested within j group unit*	*Two level hierarchical data structure. Continuous dependent variable with an approximately normal distribution.*
b_{0j}	*Intercept for the j group-level unit*	
b_{1j}	*Regression coefficient associated with the individual level predictor I_{ij} for the j group-level unit*	
I_{ij}	*Individual-level covariate of the i individual in the j group*	
ε_{ij}	*Individual-level error coefficient for the i individual in the j group*	*Errors within each group are assumed to be independent and normally distributed with a mean of 0 and a variance of σ^2*

Where b_{0j} and b_{1j} are the context specific regression coefficients carried over from the first equation. In this stage they are modeled as group-level variables. C_j is the group-level or contextual covariate , U_{oj} and U_{1j} are errors in the group level equations (also know as macro errors) and are assumed to be normally distributed with a mean 0 and variances of τ_{00} and τ_{11}. The variable U_{oj} measures the unique deviation of each group from the overall intercept γ_{00} after accounting for the effect of Cj. The variables τ_{00} and τ_{11} are variances of the group intercepts and group slopes after accounting for the group level variable Cj, τ_{01} represents the covariance between intercepts and slopes. τ_{01} is positive as the intercept increases and the slope increases.

Table 2.3 Explanation of second stage group-level equation (from Diez-Roux 2001)

Equation term	*Explanation*	*Assumptions*
b_{0j}	*Intercept for the j group unit*	
γ_{00}	*overall mean intercept adjusted for* C_j	
γ_{01}	*overall slope adjusted for* C_j	
C_j	*Group-level covariate or predictor*	
U_{oj}	*Random effects of the j group-level unit on the intercept adjusted for* C	*assumed to be normally distributed with a mean 0 and variances of* τ_{00}
b_{1j}	*Slope for the j group unit*	
γ_{10}	*regression coefficients associated with the group level predictor* C *relative to the group level unit on the intercept*	
γ_{11}	*regression coefficients associated with the group level predictor* C *relative to the group level unit on the slope*	
U_{1j}	*Random effects of the j group-level unit on the slope adjusted for* C	*assumed to be normally distributed with a mean 0 and variances of* τ_{11}

Multilevel analysis summarizes the distribution of the group-specific coefficients in terms of two parts. One is fixed and unchanging and the other is a random part that varies from group to group. Group level errors are assumed to be independent across contexts and independent of individual-level errors.

The above models can be combined into a final random-effects model that will include:

Fixed Effects of:	Random Effects of:
Group level variables γ_{01}	Random intercept $\mathbf{U}_{oj}$
Individual level variables γ_{10}	Random Slope $\mathbf{U}_{1j}\boldsymbol{I}_{ij}$
And their interaction on γ_{11}	Individual level errors ε_{ij}
The individual-level outcome $\boldsymbol{Y}_{ij}$	

The combined equation:

$$Y_{ij} = \gamma_{00} + \gamma_{01} C_j + \gamma_{10\,j} I_{ij} + \gamma_{11} C_j I_{ij} + U_{oj} + U_{1j} I_{ij} + \varepsilon_{ij}$$

The combined equation uses covariates from both stages (*C* and *I*) along with a term ($\gamma_{11} C_j I_{ij}$) that is considered to be cross-level and a complex error term ($U_{oj} + U_{1j} I_{ij} + \varepsilon_{ij}$) to model the interaction between levels. The errors in the combined model show a complex interaction in which individual-level errors are dependent upon the group in which they are nested. Thus, the assumption of independent normally distributed errors in standard regression models is violated and special techniques must be used to estimate parameters.

Multilevel Analysis for Binary Response

Health data often measure incidence or outcome and as such often is a qualitative or discrete measurement. The multilevel model will differ slightly for a discrete dependent variable. For example, in this study low birth weight will be a binary variable where the outcome is =1 if low birth weight and =0 for a normal or high birth weight. In such an instance a linear regression model cannot be used because the error terms will be heteroskedastic, not normally distributed (due to there being only two values) and use of a linear regression could potentially lead to probabilities greater than 1 and less than 0. Therefore, it is necessary to use a logistic multilevel regression analysis. A logistic regression analysis is a non-linear transformation of the basic linear model. This will constrain the estimated probabilities to fall between 0 and 1. The transformation of the linear multilevel analysis to a non-linear logistic multilevel analysis for a dichotomous dependent variable and continuous predictors will appear as follows (Goldstein and Rasbash 1996; Barbosa and Goldstein 2000; Rice 2001):

For a binary outcome where:

$$Y_{ij} = \begin{cases} 1 & \text{if } Yij \rangle\, 0, \\ 0 & \text{otherwise} \end{cases}$$

And the probability of observing a $Y_{ij}= 1$ is:

$$P(Y_{ij} = 1 \,|\, \mathrm{x1ij}) = P(Y_{ij} > 0 \,|\, \mathrm{x1ij}) = P(\varepsilon_{ij} > -b_{0j} - b_{1j}I_{ij} + \varepsilon_{ij}) = F(b_{0j}+b_{1j}I_{ij} + \varepsilon_{ij}) = \pi_{ij}$$

The first step is to define the *logit* link function at either the individual or the contextual level. The *logit* model for an individual level equation:

$$\pi_{ij} = f(b_{1j}I_{ij} + \varepsilon_{ij}) = \{1+ \exp(-[b_{1j}I_{ij} + \varepsilon_{ij}])\}^{-1}$$

Where π_{ij} is the expected value of the response variable and f is a non-linear function of the linear predictor $b_{1j}I_{ij}$.

For the Combined equation of group and individual-level variables the above equation is placed in a multilevel framework (Goldstein 1996):

$$Y_{ij} = \pi_i + \varepsilon_{ij} z_{ij}$$

$$\text{Where } z_{ij} = \sqrt{\pi_{ij}}(1-\pi_{ij})/n_{ij}$$

Socioeconomic Status and Negative Health Outcomes

Risk factors for low birth weight include individual-level medical factors as well as individual and group level demographic risk factors. The demographic risk factors include low socioeconomic status of the mother, low educational attainment, age, race and marital status (Kiely et al. 1993). While educational level, age, race and marital status can all be obtained from vital records the socioeconomic status of the mother is not readily available and must be obtained via alternative methods. Yet, many researchers feel that socioeconomic status of the mother one of the most important factors influencing low birth weight as well as many other health outcomes (Pickett and Pearl 2001). Studies have shown that socioeconomic status influences health outcomes even amongst those with a high socioeconomic status (Macintyre 1994). Macintyre (1994) found less advantaged individuals had poorer health outcomes that did the more advantaged, even when the population of study was of individuals with a relatively high socioeconomic status.

Including socioeconomic-status in the study of health outcomes serves a dual purpose. Primarily, it is a way to account for the influence of the structural location of groups and individuals within a population. Additionally, socioeconomic status accounts for the context of exposures that may be protective or detrimental to a group or individual throughout the life course (Brown et al. 2004). Due to the increased interest in contextual influences on health outcomes, several studies in the past decade have illustrated that social and economic deprivation are direct influences on negative health outcomes.

(Brown et al. 2004; Marmot 2002; Lynch et al. 1997; Krieger et al. 1997; Kaplan et al. 1996; Haan et al. 1987; Backlund et al. 1996; Haan et al. 1996).

Mortality Studies

Several studies have demonstrated a statistical relationship between all cause mortality and those living in areas of low socioeconomic status. (Anderson et al. 1997; Smith et al. 1998; Haan et al.. 1987; Kaplan et al. 1997; LeClere et al. 1997). This relationship has been explored with various single and composite indices in both the UK and US. Smith et al. (1998) report a relative risk of 1.34 in men for all cause mortality in the areas of highest socioeconomic deprivation, as calculated by the Carstair's index of deprivation and a relative risk of 1.26 for women when compared to those living in non deprived areas. Additionally, Anderson et al. (1997) report a relative risk of low versus high-income men equal to 1.26 for white men and 1.49 for black men in their study of black and white adults from the US National Longitudinal Mortality Study.

Chronic Conditions

The outcomes of the chronic condition studies were similar to the mortality studies. Several different indices were used, as were different methodologies and different populations. Diez-Roux (1997) reported significant influence of socioeconomic status on high blood pressure readings in the US. Smith et al. (1998) reported similar findings in their study in the UK . Pickett and Pearl (2001) conducted a literature review of all publications prior to 1998 referencing neighborhood socioeconomic status in developed countries. Twenty-five studies were identified that met their criteria. The criteria were that the study must be published in English, for developed countries, adjusted for individual income level and found through keyword search on Index Medicus. Of those 25, 23 were found to have statistically significant relationships between neighborhood socioeconomic deprivation and negative health outcomes. Additionally, Subramanian and Kawachi (2004) conducted a literature review of multilevel studies of income inequality and health. While not a complete measure for socioeconomic status of an area or an individual, it is in fact, generally agreed upon in the literature that socioeconomic deprivation is composed of both social and material deprivation, income inequality is a good measure of economic deprivation and as such may shed some light on the influence of economic deprivation as compared to social deprivation. Subramanian and Kawachi (2004) identified 21 studies in their review. Of the 21 identified studies, 10 found significant relationships between income deprivation and negative health outcomes.

Socioeconomic Status and Health

There exists a paucity of explanations as to the combination of individual and ecologic factors responsible for the effect of socioeconomic status on health. However, the literature suggests that at least some of this is due to ecological influences, more specifically the neighborhood of residence of an individual. The neighborhood in which a person lives may influence health outcomes in a number of ways. The availability of healthcare services, lack of infrastructure, stress due to crime and poverty, absence of places to exercise safely, prevalent attitudes regarding health and healthy lifestyles as well as availability of healthy foods all are neighborhood variables that may influence an individual's health (Pickett and Pearl 2001).

An alternative explanation may be that persons of a more economically and socially deprived area may perceive their place in the social environment to be lower. Thus, bringing into play not only physical and economic effects on individuals but psychosocial as well (Hawe 1998; Lynch et al.. 1998; Lynch and Kaplan 1997). The implications of this are that the neighborhood effects may exhibit effects in broad contexts over and above the most commonly studied variables.

The idea of broad contextual effects can be found prominently in community psychology research and in architecture and design theory. The most commonly applied terminology to this phenomenon is the ‘activity setting’ or ‘participatory place-making’. This is the idea that a place can have different meaning to different people based due to the multi-use nature of an area. Hawe (1998) uses schools as an example. A classroom in a school is used for children during the day and for community meetings at night. Thus, different individuals may have different perceptions of the same place and its influence on them. This may hold true for and individuals “neighborhood” context as well in that individuals relate and respond to their environment based on the distribution of certain components, like wealth, physical resources, time spent in a particular location, the people in that location, symbols and roles individuals relate to or participate in (Hawe 1998; O’Donnell et al. 1993). Geography also uses similar ideas within the ‘place integration’ theoretical framework (Dovey, 1985).

Index of Deprivation

The renewed interest in context and its effect on health places specific importance on geographic variation of social and economic deprivation. Approaching neighborhood effects on health outcomes from a geographic perspective requires an area level analysis. There are several benefits to this approach, primarily, the availability of census data. Census data allow for relatively quick and cost effective analysis of geographic areas. Additionally, they allow for the accurate linkage of data to existing political boundaries. Area level analysis also allows the researcher to quickly visualize spatial patterns of socioeconomic status and compare that with spatial patterns of disease through the use of GIS mapping technology. This may provide the opportunity to determine the necessary delivery of health care and identify areas of high risk for adverse health outcomes. Kreiger et al.. (2003) have found that census based measurements of socioeconomic deprivation are useful, when linked to individual level records, (geocoded) at predicting adverse health outcomes. Numerous other studies have supported the utility of an area-based measurement of deprivation (Carstairs 2000; Reienveld et al. 2000; Townsend 1987; Jarman 1984).

There are, however, drawbacks to the area level analysis of socioeconomic status on health outcomes. The main criticism of area level analysis is they still do not properly deal with the ecological fallacy. Put another way, many studies do not accurately address whether the effect seen is a compositional one or a contextual one (Subramanian and Kawachi 2004). As previously discussed the ecologic fallacy is basically the incorrect assumption that all individuals living in a given area share identical characteristics with that area. The ecological fallacy must be taken into consideration but area level analysis must not be completely ruled out. Taking individual level variables and aggregating them may create the opposite problem, commonly referred to as the atomistic fallacy. However, it is the contention of this research that multilevel analysis is a methodology particularly suited to overcome both the ecological and atomistic fallacy when used properly (see introduction). Additionally, many studies do not properly examine the methodological issue of compositional versus contextual effects (Diez-Roux 2004; Subramanian and Kawachi 2004).

Thus it is necessary for a researcher to develop a way to account for neighborhood effects. One such solution is to develop an index ranking small "neighborhoods" or area levels of deprivation. Data are readily available for pre-defined, political boundaries. However, data are almost non-existent for more difficult to define areas. Additionally, some areas have moving or ephemeral boundaries (e.g.,; social groups). Thus, the question becomes; where does one obtain the data for such groups and once obtained how those data can be linked to the individual? (Diez-Roux 2004) Thus, it should be noted that for a more accurate investigation of the distribution of causal factors, and to avoid potential misspecification, the "groups" should be more rigorously defined (Diez-Roux 2004; Pickett and Pearl 2001). This is the most difficult aspect of multilevel analysis. Raudenbush and Sampson (1999) have begun to address this question with a statistical methodology called Ecometrics, which promises to assess the validity of ecological contexts, specifically neighborhood settings. Through the use of interviews, direct observation of multiple observers and video analysis of neighborhoods, sources of error in multilevel analysis are highlighted and considered (Raudenbush and Sampson 1999). This approach, which is indeed promising, is time consuming and not well suited for an investigation such as this one.

A composite measurement of deprivation is necessary to assess a geographic area's socioeconomic status. Such a measure should combine data from a number of variables in a way that places a particular area along an axis of deprivation ranging from the most deprived (poverty) to the least deprived (affluence). What this implies is that particular values for the variables making up a given index are more desirable than others. That is to say that it is more desirable for an individual to be employed and to have a car, for example (Carstairs 2000). Additionally, Krieger et al. (2003) define three criteria that should guide the development of a deprivation index. The researcher should have an existing definition and conceptual framework of socioeconomic position and social class from which to work. Additionally, literature supported evidence for the detrimental health effects of material deprivation is necessary for the meaningful application of a deprivation index. Finally a deprivation index should consist of a measure or measures that can be compared over time and space.

Socioeconomic indices of deprivation are less common in the literature in the United States than in the UK. This is however, beginning to change with the advent of new multilevel methodologies. Through a literature search, 28 common area based socioeconomic measures were identified (Table 2.6). The findings of this search are consistent with Krieger et al. (2003) with a few minor additions. What is of particular interest is the lack of measures of social deprivation and the focus on material influences of deprivation. This is especially common in the US literature. While the argument can be made from a Marxist framework, that the material influences the social, the explanation is, however, most likely that the US decennial census is biased toward material measurement. That is most of the variables contained within the U.S. Census measure the material. This may be affirmation of the Marxist viewpoint or the reinforcement of the focus on material attainment of US society as a whole. Or conversely it may only be that theses values are most easily and reliably measured. Data from the decennial U.S. census does not lend itself to the creation of a socioeconomic deprivation index. At best a composite index of material deprivation can be derived from several variables found in the Summary Tape File 3. As such, numerous studies have attempted to create socioeconomic indices through varying methodologies By far, the Townsend Deprivation Index (Townsend 1988) and the Carstairs Index (Carstairs 2000) are both indices commonly used in the UK to measure relative material deprivation (Carstairs 2000) are the most commonly encountered composite deprivation indices in the literature. Numerous indices have been created that are highly correlated with both indices (Krieger et al. 2003). However, due to the differences between the US and UK census there is some difficulty in directly applying an index created in and specifically for the UK in the US. Additionally, indices created for European populations may not be applicable to US populations due to the homogeneity of the socioeconomic status of some European countries. Therefore caution must be exercised before applying an index to a population for which it was not designed (Pearl and Pickett 2001; Reijnveld 1998).

Table 2.4 Commonly Encountered Group-level Indices of Deprivation (from Pickett and Pearl 2001)

Index	Type of Measure	Variables
Working Class ***Krieger et al. 1997***	Material Deprivation	% of persons employed in non-supervisory roles as a percent of persons employed in one of the US Census occupational groups
Unemployment *Krieger et al. 2003*	Material Deprivation	% of individuals >16yrs in the labor force who are unemployed
Median Household Income *Krieger et al. 2003*	Material Deprivation	Median household income (1989) $30056
Low Income	Material Deprivation	% of households with income < 50% of the US median household income
High Income *Krieger et al. 2003*	Material Deprivation	% of households with income >400% of the US median household income
Below Poverty US Census Bureau 1997	Material Deprivation	% of persons below the federally defined poverty line. Average equaled $12647 for a family of 4 in 1989
Expensive Homes *Krieger et al. 2003*	Material Deprivation	% of owner occupied homes >400% of the US median value of owned homes
Educational Attainment *Krieger et al. 2003*	Social Status/Material Potential	% of individuals >25 years old with less than a 12 grade education (low). Conversely % of individuals > 25 years old with at least 4 years of College (high)
Crowding *Krieger et al. 2003*	Social Environment/Material Deprivation	Percentage of households with >1 person per room
Socio-economic Position 1 *Krieger et al. 2003*	Material Deprivation	% of individuals below poverty level, working class, and expensive homes
Scio-economic Position 2 *Krieger et al. 2003*	Material Deprivation	% of individuals below poverty level, working class, and high income
Socio-economic Economic Position Index *Krieger et al. 2003*	Material Deprivation	% working class, % unemployed, % below poverty level, % individuals with low educational attainment, expensive homes, and median household income
Carstairs (UK) ***Carstairs and Morris 1991***	Material Deprivation	Male unemployment, automobile ownership, social class, crowding Variables are not weighted
Jarman (UK) ***Jarman 1983***	Needs For Primary Care Services	Unemployment, low social class, unskilled labor, overcrowding, single parent household, # children under 5yrs., pensioner living alone, moved in past year, ethnic minority. Variables are weighted.
Townsend (UK) ***Townsend 1987***	Material Deprivation	Unemployment, low social class, not owner occupied, lacking amenities
DoE (UK) ***DoE 1995***	Needs for local authority services	Unemployment, overcrowding, lacks amenities, children in unsuitable accommodations, children in low earner households, not in educational system, low income support recipients, low educational attainment, derelict land.
Deprivation Index (US) Andrulis et al.. 2001	Material Deprivation	Poverty rate, violent crime rate, unemployment rate, educational attainment, per capita income, ability to speak English. Variables are not weighted.
Care Need Index (Sweden) Sundquist et al. 2003	Material Deprivation	Elderly living alone, foreign-born people, unemployed people, single parents, residents who have moved, people with low economical, status, children under age 5. Variables are weighted
Mayer-Jencks' Material Hardship Measure ***Mayer & Jencks'1989***	Material Deprivation	Calculates a family's income to needs ratio, including; healthcare and food affordability.
Gini Coefficient ***Gini 1912***	Material Deprivation	Income inequality (half of the arithmetic average of the absolute differences between all pairs of incomes in a population normalized on mean income)
Robin Hood Index	Material Deprivation/Income/Inequality	The proportion of money that must be transferred from the rich to the poor to achieve equality.

Table 2.4 (Continued) Commonly Encountered Group-level Indices of Deprivation (from Pickett and Pearl 2001)

Index	Type of Measure	Variables
Thiel Entropy ***Thiel 1967***	Material Deprivation/Income Inequality	Measure of income inequality derived from information entropy theory
Socioeconomic Deprivation index (US) *Sing et al.*	Material Deprivation	Principal component analysis selected variables: Educational attainment, occupational status, Median family income, income disparity, median home value, median gross rent, unemployment rate, occupied houses with telephone, occupied houses w/o complete plumbing
Atkinson ***Atkinson 1970***	Material Deprivation/Income Inequality	Calculates equity density average income, which is the measurement of per capita income which if enjoyed by everybody would make total welfare exactly equal to the total welfare generated by the actual income distribution
Cogdon Index	Social Deprivation	Mobility of Individuals, number of single person households for persons <65, and private renting
Index of Multiple Deprivation (IMD) ***Jordan et al. 2000***	Material and health Deprivation/Access to services	32 Variables measuring income, employment, health deprivation, disability, education, skills, training, housing and geographical access to services.
Diez-Roux et al.. *Diez-Roux et al. 2001*	Material Deprivation	Variables selected through factor analysis. Log of median household income, log of median value of housing units, % of households receiving interest, dividend or net rental income, % of adults (>25yrs) who completed high school, % of adults who completed college, occupational status. Variables are not weighted.
US CDC Index of Local Economic Resources Casper et al. 1999	Access to material resources	White collar employment, unemployment, and family income.

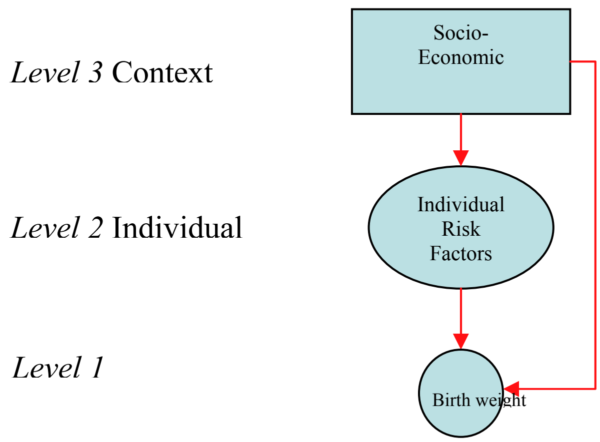
CHAPTER THREE:

THEORETICAL FRAMEWORK & METHODOLOGY

Theoretical Framework

The multilevel model used in this research assumes a theoretical framework as seen in figure 3.1. This framework is modified from the conceptual model developed by Duncan et al. (1996) figure 3.2. In the theoretical model, an individual level response (low birth weight in this case) is directly influence by individual level factors (race, smoking and parity, for example). Individual level factors are influenced by contextual level variables (in this case neighborhood socioeconomic status). Additionally, this study proposes that the individual level outcome may not only be influenced by individual level factors but by contextual level variables as well. What this suggests is that a persons' neighborhood of residence will influence the development of certain risk factors for low birth weight as well as directly influence low birth weight outcomes.

Figure 3.1 Theoretical Framework (Modified from Duncan et al. 1996). Lines of influence are in red. Contextual levels are in blue shapes.

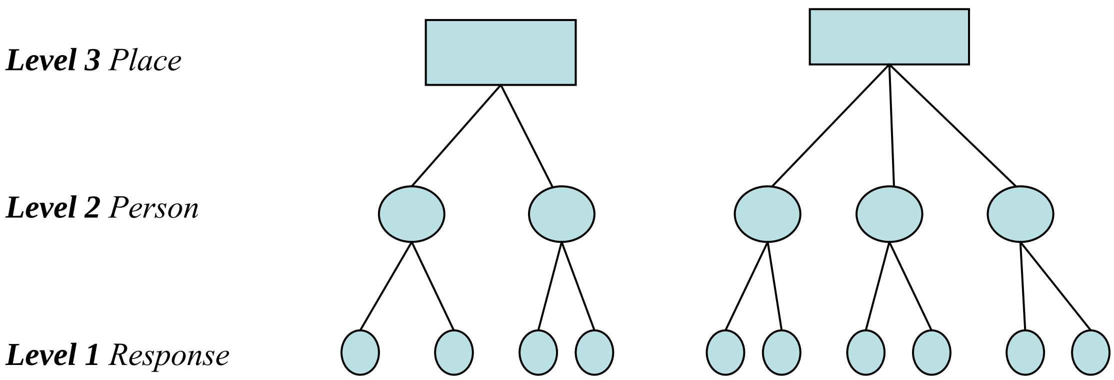


The qualitative equivalent in geography can be seen in the critical realist explanation of spatial variability. The likelihood of contextual variation requires methodology, which accounts for the variability across time and space. That is to say that, human beings will behave differently at different times and under different circumstances (Peet 1998). The geography of a particular area is as important as the individuals that comprise it. The spatial landscape has the ability to influence individual level outcomes.

Research Model

The research model for this study follows the proposed multilevel structure conceptual model found in Duncan et al. (1998) figure 3.2. In this conceptual model, individual level responses are nested within individual that are nested within groups. This model could be extended to include groups nested within regions. Additionally groups may be nested within different times as in a repeated measures or longitudinal study.

Figure 3.2 Multilevel Conceptual Model (Duncan et al.. 1996)



Research Question

What are the relative roles of individual-level, and ecologic, risk factors in explaining the geographic variability in the occurrence of low birth weight outcomes in the State of Florida?

Research Hypothesis

It is hypothesized that, after adjusting for individual level variables, the odds of having a low birth weight child are higher for a mother living in a neighborhood with a high deprivation index score than a mother living in a neighborhood with a low deprivation index score. Additionally, a statistically significant portion of the spatial variation of low birth weight outcomes in the State of Florida is due to neighborhood effects.

Description of Data

For areas with greater than 40 live births the 2000 US Census block group, and tract were used as proxies for neighborhood of residence. Block groups with less than 40 live births were aggregated to the Census 2000 Tract level. The 2000 census was used because for some births only a 2000 block group or Track were identified. This is due to the changing boundaries between the 1990 and 2000 census. Census variables were obtained from the U.S. Census web site as dbf files. The census data were used to represent the group level variables. The variables obtained were per capita income, number of unemployed, linguistic isolation, number of individuals living below the federal poverty level, number of individuals with an automobile, and level of education. In addition to the Census data, Vital Statistics birth data for 1992-1997 from birth certificates were used as measures of individual level variables. The Vital Statistics data contains gestation parity, gain during pregnancy, as well as age, smoking status, education, race, and marital status of the mother.

Methodology

Birth record data were obtained for all singleton births in the state of Florida for the years 1992-1997 (n =1,030,443). For identification purposes, each individual record was given a birth identification number. The individual records were linked to the census block group of residence (average of 1000 persons) of the mother. Census block groups were used as proxies for neighborhoods. This methodology is similar to that found in Diez-Roux et al. (2001) in their study of neighborhood influence on the incidence of cardiovascular disease. This methodology was chosen for two reasons. First, the predefined boundaries of the U.S. Census allow for easy data linkage. Without this linkage the task of assigning census level data to areas with alternatively constructed boundaries would be extremely difficult and time consuming. Pickett and Pearl (2001) noted that this was a commonly accepted methodology. Moreover, of the studies they examined in their critical review, all but one use data linked to census boundaries. However, for a more accurate investigation of the distribution of causal factors, the neighborhood of residence should be more carefully designed and conceptualized (Pickett and Pearl 2001).

In addition to using Census Block Groups, individual birth records were linked to the 1990 and 2000 U.S. Census Tract boundaries. The purpose of this was to compare the results obtained from the block group-level model and to possibly determine which level (Block Group or Census Tract) the deprivation index explained the variance seen in low birth outcomes across groups.

A material deprivation index for all block groups in the state of Florida for 1990 and 2000 was created. This study was only concerned with material deprivation due to the nature of the US Census data. Census data are demographic and material in nature, there are no direct measures of social capital or social environment. Data from the Summary Tape File 3A were used to construct an index. Similar to Andrulis et al. (2004), poverty status, educational attainment, linguistic isolation, per capita income, and unemployment rate were included in the constructed index. However, Andrulis et al. (2004) included crime rates in their index. There are two reasons this is not included in the constructed index. Most importantly is the geographic scale of the data. Crime rates are generally only available for MSA's. (Andrulis et al. 2004) Calculated their index for MSA's as proxies for cities. This research is more concerned with neighborhood contextual effects. Therefore, data that only exist at larger aggregate areas is of little use to this study. In addition to the index variables defined by Andrulis et al. (2004) this study has included two additional variables: vacancy rates and automobile ownership. The explanation of variable choice is explained in the following paragraphs.

Explanation of Group Level Variables

Per Capita Income

In their literature review, Subramanian and Kawachi (2004) found a potential relationship between income distribution and health outcomes. They hypothesize that although some studies show strong statistical relationships between low income and negative health outcomes, the failures of these to adequately explain the causal mechanism of income's influence on health and the failure of others to find such a relationship is due to the fact that income is only one dimension of deprivation and as such other factors should be considered. Therefore, the annual per capita income of each block group was obtained from the US Census STF3 and included in the model of deprivation

Availability of an Automobile

Several studies have shown that lack of available transportation plays a strong role in influencing health outcomes (Rittner and Kirk 1995; Melnikow et al.. 1997; Williamson and Fast 1998; Takano and Nakamura 2001). The lack of adequate transportation may act as a barrier to the receipt of health services as well as influencing access to food and social networks (Bostock 2001; Brown et al. 2004). As Florida has little in the way of effective public transportation I am including the availability of automobiles in the deprivation index. The data regarding access to one or more vehicles was obtained from the U.S. Census STF3. The percent of individuals with access to no automobile was calculated from the Census data. This was then added to the deprivation index.

Linguistic Isolation

Linguistic isolation has been shown to influence self-care behaviors and health literacy. Additionally patients with a language barrier, specifically Spanish-speaking Latinos, are less likely to have a regular source of health care and are less likely to report satisfaction with their health care (Brown 2004; Fiscella et al. 2002; Schur ad Albers 1996; Hu and Covell 1986). Thus, linguistic isolation may be an influence on pre-natal care and understanding of healthy practices during pregnancy. It is estimated that only 40% of Latinas utilized prenatal care in the District of Columbia (Kaiser Family Foundation).

Poverty Rate

Krieger et al. (2003) conducted an analysis of single and composite measures of socioeconomic deprivation on childhood lead poisoning and low birth weight. For the outcome of low birth weight their study they report an odds ratio of 2.08 (1.98 to 2.19, 95% Confidence Interval (CI)) for mothers living in poverty in the state of Massachusetts as defined by the US Census Bureau. Additionally, an odds ratio of 1.97 (1.65 to 2.13, 95% CI) was reported for mothers living in poverty in Rhode Island (Krieger 2003).

Educational Attainment

The level of educational attainment has been used as a predictor for low birth weight as part of a composite index or independently in several studies (Andrulis 2004; Krieger et al.. 2003; Pearl et al. 2001; Pickett and Pearl et al. 2001). Krieger et al. (2003) reports a low birth weight odds ratio of 1.97 (1.86 to 2.08 95% CI) for singleton births in Massachusetts to mothers of low educational attainment and an odds ratio of 1.91 (1.65 to 2.22 95% CI) for singleton births in Rhode Island.

Lower educational attainment has been observed to negatively influence health literacy (Gazmararian et al. 1999; Baker et al. 1998). Health literacy is linked to health status. Patients with lower educational attainment are more likely to be admitted to the hospital than their more educated counterparts and less likely to be able to recognize signs and symptoms before a serious problem develops (Gazamararian et al. 1999; Baker et el 1998; Williams et al. 1998; Baker et al. 1997).

Unemployment Rate

Unemployment rate is one of the most commonly included metrics in studies of area based socioeconomic influence on negative health outcomes (Andrulis 2004; Brown et al. 2004; Krieger et al. 2003; Pickett and Pearl 2001; Pearl 2001). For mothers living in areas of high unemployment the odds ratio for low birth weight is 1.72 (1.61 to 1.84 95% CI) (Massachusetts) and 1.51(1.37 to 1.67 95% CI) (Rhode Island) (Kriger et al. 2003). Additionally, Epstein et al. (1985) report that less effective patient-provider communication is observed when the patient is of a lower occupational status. This may, in turn, influence antenatal behaviors and care practices.

Once all variables were obtained and manipulated a Z-score was calculated for each variable. Where the $Z - score = (x - \mu / \sigma)$, where x is the block group's individual value of a variable, μ is the average for the block groups, and σ is the standard deviation of the variable for the city. The sum of a block group's Z-scores is a block group's index of deprivation. The larger the score the more deprived an area is assumed to be (Andrulis 2004).

Once the z-scores were calculated, a correlation matrix was created for the 1990 variables and 2000 variables using S-Plus to determine if certain variables were measuring a variable more than once or if there was correlation between variables. A table of *Pearson Product-Moment Correlation Coefficients* (r) was created to examine the degree of the linear relationship between all possible combinations of the coefficients that comprise the deprivation index. The calculated correlation coefficients may be equal to any number between –1.00 and 1.00. A score of –1.00 represents a perfect negative relationship between two variables while a score of 1.00 represents a perfect positive relationship. The results can be seen in tables 3.1 and 3.2.

When examining the variables in the 1990 deprivation index, the strongest relationships can be seen occurring between Vehicle Ownership (Z-VehOwn) and Poverty, with a coefficient of .774. Poverty also showed a strong correlation with educational attainment as well as income and unemployment. Education attainment also showed a strong correlation with a number of variables, particularly income. Educational attainment and per capita income show a correlation coefficient of -.647. Additionally, education and vehicle ownership also showed a strong correlation with a score of .633. The remainder of the variables showed a moderate to small degree of correlation.

The variables in the 2000 deprivation index showed some correlations. Poverty and vehicle ownership showed the strongest correlation (r=.623). Educational attainment and unemployment had a correlation coefficient of .574. Other variable combinations showed a moderate to small degree of correlation.

As evident in table 3.1 the 1990 index shows a good deal of correlation between variables while the 2000 index does not. Therefore, the 1990 index will only be used as a reference to compare with the 2000 index. This is to avoid unduly weighing certain areas over others. The use of an index with a high degree of correlation amongst its composite variables would artificially inflate the deprivation z-score. The individual variables that make up each index will be also used as the group level variable in the multilevel analysis to determine the effect each has on low birth weight.

Table 3.1 Correlations for data in: 1990 Deprivation Index

	Z-LingIso	Z-EduAttain	Z-VehOwn	Z-Poverty	Z-Percap	Z-Unemp
Z-LingIso	1.00	.522	.306	.268	-.260	.260
Z-EduAttain	.522	1.00	.633	.720	-.647	.559
Z-VehOwn	.306	.633	1.00	.774	-.421	.574
Z-Poverty	.268	.720	.774	1.00	-.568	.639
Z-Percap	-.260	-.647	-.421	-.568	1.00	-.436
Z-Unemp	.260	.559	.574	.630	-.436	1.00

Table 3.2 Correlations for data in: 2000 Deprivation Index

	Z-LingIso	Z-EduAttain	Z-VehOwn	Z-Poverty	Z-Percap	Z-Unemp
Z-LingIso	1.00	.424	.076	.109	-0.075	.216
Z-EduAttain	.424	1.00	.368	.475	-.310	.547
Z-VehOwn	.076	.368	1.00	.623	-.273	.287
Z-Poverty	.109	.475	.623	1.00	-.390	.347
Z-Percap	-0.075	-.310	-.273	-.390	1.00	-.197
Z-Unemp	.216	.547	.287	.347	-.197	1.00

In addition to group-level variables individual level variables were obtained from vital records data. Dummy variables were constructed for each of the individual level variables as the data were obtained in categorical format. Once the data were re-coded and converted from database IV format to tab delimited format it was imported into *MLwiN for* multilevel analysis and modeling. The conversion was necessary to allow for the proper hierarchical data structure to be set-up.

Explanation of Individual Level Variables

The individual level variables included in the multilevel models are:

- Ethnicity of the mother
- Age of the mother
- Smoking,
- Marital status,
- Parity
- Weight gain during pregnancy
- Gender of Baby

Ethnicity

Ethnicity of the mother was also included as an individual-level variable due to the racial and ethnic disparity in low birth weight outcomes. Black Non-Hispanic mothers give birth to 13 times more low birth weight infants than their white counterparts. Among Hispanics low birth outcomes are 6.5% while white outcomes are 1.1%. Therefore, it is important to adjust for ethnicity when seeking out the causes of low birth outcomes (Kiely et al. 1993).

Odds ratios were calculated by taking the exponents of the coefficients of the ethnic category variables from a single-level model. The odds of a Black Non-Hispanic mother having a low birth weight baby are 2.27 times that of a White Non-Hispanic mother. While the odds of a Hispanic mother was not much higher that that of a White Non-Hispanic mother (1.06 vs. 1.00). The predicated probability of a Black Non-Hispanic mother having a low birth weight outcome is 10.7 % compared to 5.3% in Hispanics (which is comparable to White Non-Hispanics a 5%).

The data clearly show the difference in low birth weight outcomes amongst the three ethnic categories. This is fully supported by numerous studies in the low birth weight literature (Kiely et al. 1993). It is worth noting that the difference in Hispanic and White Non-Hispanic low birth outcomes is smaller that the nationally reported difference.

Age of Mother

The age of the mother during pregnancy has been shown to influence the likelihood of a low birth weight outcome. Women who have a first time pregnancy under the age of 17 and over the age of 35 are more likely to have a low birth weight outcome when compared to women between the ages of 18 and 34.

The age of the mother in years at time of birth was divided into three categories. The standard Census categories of 12-14, 15-18, 19-24, 25-29, 30-34, 35-39, 40-44 and 45+ were collapsed to create the three categories used in this study. The reference category used was 18 to 34 years of age. Ages 12-17 was the next category and ages 35-54 was the final category.

The results of the tabulation and modeling in the MLwiN software package showed 14.5% of all low birth weight babies were born to mothers under the age of 17 years old. Additionally, 11.3% were born to mothers over the age of 35. The odds ratio for a low birth weight occurrence for a mother under the age of 17 years was 1.77 while the odds ratio for a mother over the age of 35 was 1.18 compared to a mother between the age of 18 and 34 years old.

Smoking

A strong association between smoking and an increase of low birth weight outcomes has been reported in the literature and in larger studies a dose response curve has been established (Keffier et al. 1993). For example the Centers for Disease Control and Prevention conducted a study of risk factors during pregnancy on low-income mothers for the years 1978-1998. This study showed that amongst women who had low birth weight babies (6.9%), there was a high prevalence of smoking during pregnancy (29.7%) (Fichtner et al. 1990).

First, the relationship between low birth weight (binary outcome) and smoking habit of the mother (also a binary variable) was examined. Smoking status was categorized as either non-smoking or smoking. The non-smoking category was used as the reference category. A tabulation of percent low birth weight births by smoking status of the mother was generated in MLwiN. This tabulation showed that amongst women who had a low birth weight baby, the prevalence of smoking was 10.7%. This also showed that women who smoke are almost twice as likely to have a low birth weight baby that a non-smoking mother. Odds ratios were calculated by taking the exponents of the coefficients of the smoking category variables . The odds of a mother who smokes having a low birth weight baby is 1.93 times that of a non-smoking mother. From these results it is clear that the percentage of low birth weight infants born to mothers who smoked in higher than those born to non-smoking mothers although not as high as Fitchner et al. (1990).

Marital Status of the Mother

The marital status of the mother during the pregnancy is a categorical variable with the responses being either married or not married. Generally, unwed mothers have a slight increase in the likelihood of having a low birth weight baby (Kiely 1993). The tabulation of marital status of the mother shows a slight increase of the result of the single-level logistic regression. Among low birth weight outcomes 9.2% were to unwed mothers compared to 4.9% among married mothers.

Parity

Parity, defined in this study, as the number of previous live births, has been shown to have an effect on low birth weight outcomes. Women with low parity (one previous birth) are at a decreased risk of having a low birth weight outcome when compared to women who are primiparious. However, the CDC reports that primiparous women have a 23% greater risk of a low birth weight outcome when compared to multiparous women (Kiely et al. 1993).

The relationship between low birth weight outcomes and parity was examined through the tabulation of parity categories and the running of a single level model in MLwiN. The results from MLwiN show that a woman with one previous live birth has a decreased risk of having a low birth weight infant as does a mother with two to four previous live births when compared to a woman who is primiparous. The odds ratio for a low birth weight outcome amongst primiparous women was 1.43 in this study. On the opposite end of the parity- spectrum, women with a parity of greater than 5 had an odds ratio of 1.46 when compared to women with one to four previous births.

Weight Gain During Pregnancy

According to Kiely et al. (1993) several studies have found significant correlation between very low weight gain and low birth weight outcomes. For the purposes of this study weight gain during pregnancy is a categorical variable divided into 3 categories, low, good and excessive. Weight gain was measured in pounds gained during pregnancy. To examine the effects of various levels of gain on a level 1 birth outcomes the weight gain was divided into categories as seen in table 3.3.

Women with low weight gain comprised 15.7% of the low birth weight outcomes. The odds ratio for women of low weight gain was 3.85. Excessive weight gain, by contrast, seemed to have a protective effect. The odds ratio for women with excessive weight gain during pregnancy was 0.54.

Gender of Baby

Of all low birth weight outcomes in the study sample 7% were female babies and 5% were male. The odds ratio for female babies be of low birth weight was 1.19. Thus female babies are at a slightly increased likelihood of being of a low birth weight.

In addition to the individual level variables the group level deprivation index variable was included. Alternative models were constructed using the individual level variables and one of the variables comprising the deprivation index. The definition of the variables used variables used the building of the multilevel model are explained in table 3.3.

Table 3.3 Explanation of Variables used in the construction of multilevel models.

Variable Name	Definition
Birth	Identifying code for each birth (level 1)
Block_grp	Identifying code for each block group (level 2)
Gender	Gender of baby. 1=Male; 2=Female
LBW	Low Birth Weight (Outcome) 0=birth weight >2500gm; 1=<2500gm
Smoking	Smoking status of the mother. 0=nonsmoker; 1=smoker
Depind	Deprivation Index calculated for each block group (addition of z-scores)
Marital	Marital Status of the mother 0=not married; 1=married
AgeCat	Categorical variable for age 1=12-17; 0=18-34; 2=35+
GainCat	Categorical variable for gain. 1=low birth (0-15 lbs gain); 0=(15-30 lbs gain) 2= excessive (30+ lbs)
ParCat	Categorical variable for parity. 1= Primiparous; 0= 1 or more previous births
Cons	Constant vector
Denom	Denominator vector
Pov	Z-Score for percent individual living below the poverty line (level 2)
Edu	Z-Score for percent individuals with less than a high school education
Veh	Z-Score for percent of individuals without an automobile (level 2)
Inc	Z-Score for per captia income (level 2)
Emp	Z-Score for percent individuals in the work-force that are unemployed

Two-Level Random Intercept Logistic Regression Model

The above variables were combined along with the deprivation index to fit a multi-level logistic regression model. The purpose of this was to allow for group level (block group or census tract) effects on the probability of a low birth weight outcome. The purpose of creating a two level model is to allow the effect of the group level variables, the deprivation index or variables comprising the index, to vary across groups. The groups in this study are either census block groups or census tracts. The tables 4-17-4.72 outline the results from running the two level random coefficient model. A total of 55 models were run. The models run were for all records using the 1990 deprivation index, the 2000 deprivation index, the binary deprivation index (based on the 2000 deprivation index) as well as one model for each of the variables that went into making the deprivation index. After the full models were then run one for each of the three ethnic categories was run.

The results of the model are reported as the odds ratios for both the individual level variables and the group level variables. The odds ratio is the odds an exposed individual develops the outcome divided by the odds an unexposed individual develops the outcome. Thus any value greater than 1 suggests that an exposed individual has greater odds of developing the outcome than an unexposed.

CHAPTER FOUR

RESULTS

Results

The population of study was all singleton live-births in the state of Florida for the years 1992-1997. As a result the total number of records was equal to 1,030,443. Of these births 51.2% (527,916) were male babies and 48.8 % (502,527) were female. The number of infants born to unwed mothers was 663,865 while the number born to married mothers was 964,014. The average age of the mother giving birth during the time period 1992-1997 was 26.131 years with the youngest mother being 12 years old and the oldest being 54 years old. The average parity was 1.02 previous births. The lowest parity was zero previous births and the highest was 22. Mothers on average gained 22.28 pounds during pregnancy the lowest gain was zero pounds and the highest gain was 98 pounds.

The study population was divided into three ethnic categories, White Non-Hispanic, Black Non-Hispanic and Hispanic. White Non-Hispanic births comprised 58.5% of the study sample (603171 births) compared to 55.2% statewide for 1990-2000 and 64% nationwide. Black Non-Hispanics comprised 23.8% of the sample population (244924 births) compared to 23.2% statewide and 12% nationwide for the years 1990-2000. While Hispanic births were 17.7% of the sample (182348 births) compared to 22 % of births statewide and 17% nationwide for the years 1990-2000 (Grigg et al. 2000).

Births to mothers who smoke were 13.7% of the sample population (141,769 births) compared to 21.9% statewide and 22.5% nationwide for the years 1990-2000. It should be noted however, that 607 births had no record of smoking history at all. Low birth weight births were 6.4% of the sample population (66,429 births) compared to 8% statewide and 7.6% nationally (Grigg et al..2000).

A summary of the results of the multilevel models for the block group level models can be seen in Appendix A. Table A.1 shows an odds ratio of 1.08 for the 2000 deprivation index when adjusting for individual-level factors. The 2000 poverty z-score and the 2000 per capita income z-score showed larger odds ratios. The 2000 poverty z-score had an odds ratio of 1.27 while the 2000 per capita income z-score had an odds ratio of 1.20. It should be noted that the results for models run for the 2000 variables were significant at the α =.01 level (p =.0132). Additionally the residual variance, the variance that can naturally be expected by moving from one block group to the next, was found to be less than 2%.

Table A.2 additionally shows results for the 1990 models. While the results for these models were statistically significant a α =.01. The p value was equal to 0.0185. The odds ratios were closer to 1 than the 2000 models. For comparison the 1990 deprivation index odds ratio was 1.08 while the 1990 poverty z-score was 1.02 and the 1990 per capita income z-score was 1.12.

The results of table A.1 show that a mother living in an area of high poverty, as defined by the 2000 census, has a 1.27 times increased odds of having a low birth weight outcome. While a person living in an area with low per capita income z-scores has a 1.2 times increased odds of having a low birth weight outcome.

Tables A.3-A.8 also shows the results of the models stratified by ethnic category. For White Non-Hispanic mothers, there was a 1.16 times increased odds of having a low birth weight baby living in a neighborhood with a high score on the 2000 deprivation index (odds ratio=1.16). Additionally, a 1.13 times increased odds of having a low birth weight baby was found for White Non-Hispanic mothers living in neighborhoods having a high value on the 2000 educational attainment z-score. The residual variance for these models was less than 2% and the p value was less than .01.

For Hispanic mothers the highest increase odds of having a low birth weight baby were found amongst those living in a neighborhood with a high 2000 deprivation index (odds ratio 1.12) and areas with high values for the 2000 no vehicle z-sore (odds ratio 1.12). Additionally mothers living in areas with high values for unemployment had a 1.28 times increased odds of having a low birth weight baby.

Black Non-Hispanic mothers only showed a 1.04 times increase in odds of having a low birth weight baby in areas with high 2000 deprivation index scores. The neighborhood level variable which showed the most influence on the odds of having a low birth weight outcome amongst Black Non-Hispanic mothers was linguistic isolation. Mothers living in a neighborhood with high values for the 2000 linguistic isolation z-score had a 1.12 times increase in odds of having a low birth weight baby.

The results of the multilevel models for the tract level models can be seen in tables A.9 through A.16 found in appendix A. The results show the odds ratios for both the individual level variables and the group level variables. The results are similar to the results seen in the block group level results, however, the odds ratios for the tract level variables are closer to 1.

Table A.9 shows an odds ratio of 1.18 for a mother living in an area with a high value for the 2000 poverty z-score. While a mother living in an area with a high 2000 deprivation index value had an odds ratio of 1.07 after adjusting for individual level variables. The residual variance for the census tract level model was 3% and the results were significant at the α=.01 level.

The results for the ethnically stratified models, seen in tables A.11 though A.16 in Appendix A, , for the census tract level, were also similar to the block group results with all odds ratios being closer to 1 as well. White non-Hispanic mothers living in areas with high scores on the 2000 deprivation index had an odds ratio of 1.14. It is worth noting however, that mothers living in areas with low educational attainment had an odds ratio of 1.12. Black Non-Hispanic mothers had a 1.07 increased odds of having a low birth weight baby in areas with high scores on the 2000 deprivation index. Moreover, Black Non-Hispanic mothers had a 1.12 increased odds of having a low birth weight baby in areas with high values for the 2000 linguistic isolation z-score. Hispanic mothers were at a 1.11 times increased odds of having a low birth weight baby in areas with high scores on the 2000 deprivation index. In addition, Hispanic mothers living in areas with high values on the 2000 no vehicle z-score had a 1.11 times increased odds of having a low birth weight baby.

Individual Level Results

The multilevel model constructed for this research included individual level variables. The purpose for including individual level variables was to adjust for the effects these variables have on the outcome and to examine the effect the explanatory variables had on the overall model. The inclusion of individual level variables is an important aspect of multilevel modeling. Individual level controlling factors prevent ecological bias from occurring in the model. Additionally they aid in the examination of the group level data.

If group level variables were to have show strong influence on the outcome, the individual level variables for that particular model would have shown a large decrease in their influence as seen by a drop in the reported odds ratio. This did not occur in this research. In fact, the individual level variables remained relatively stable across all of the models, indicating a small effect of the group level variables. The individual level results show that the variables that primarily influence on low birth weight outcomes area at the individual level and additionally, group level variables do not play a strong role in influencing low birth outcomes. There were a few minor exceptions, which are discussed in the following paragraphs.

Smoking

Smoking had the largest positive effect on the probability of a mother having a low birth weight baby. Odds ratios for the effect of smoking ranged from 2.25 in the White Non-Hispanic block group model to 2.08 in the Black Non-Hispanic model (see appendix A). This is wholly in-line with other findings in the literature, see Kiely et al. (1994) for a complete discussion. Generally, the influence of smoking on the outcome was modified slightly by the inclusion to group-level variables, as is to be expected in a multilevel logistic model. However, the effect varied very little with the inclusion of each of the group-level variables. It is important to note that the strength of the effect of smoking in the models in this research suggest that it is the primary risk factor for low birth weight outcomes.

Ethnicity

For the non-ethnically stratified models a Black Non-Hispanic ethnicity category had the second largest positive effect on the probability of a mother having a low birth weight baby. Odds ratios for Black Non-Hispanics ranged from 2.0 to 1.87 (appendix A) in the 2000 and 1990 block group full models. Kiely et al (1994) report that Black Non-

Hispanics have the highest rates of low birth weight babies when compared to other ethnic categories. It is interesting to note that the strength of the influence of ethnicity varied little across the various group level variable models with the exception of 1990 and 2000 poverty. The inclusion of this group level variable caused the largest decrease in the effect of ethnicity on the outcome. This suggests a differential effect of the group level variable for poverty across ethnic category. Consequently, this highlights the need to run ethnically stratified models to examine the variation of individual and group-level predictors across all ethnic categories.

Parity

After stratifying by ethnicity, parity category of the mother was the individual-level variable with the third larges positive effect on the probability of a mother having a low birth weight baby, behind weight gain during pregnancy. This research divided parity categories into primiparous or multiparous. Primiparity was defined as never having previously giving birth. Multiparous mothers were defined as mothers having previously given birth to one or more babies. Parity ranged from no previous births to twenty-two. Like smoking, the influence of parity varied little for each of the group-level variables included in the models. The odds ratio for parity ranged from 1.77 amongst White Non-Hispanics to 1.41 amongst Black Non-Hispanics in the 2000 census block group models (appendix A). It is important to note that parity did not vary with the use of different group-level variables. It did however vary across ethnic categories with the smallest effect seen in Black Non-Hispanics.

Gain

Weight gain during pregnancy was previously determined to be an important influence on low birth weight outcomes (see literature review for complete discussion). This research showed that low weight gain was highly influential on the outcome. Low weight gain had an odds ratio ranging from 1.93 in the 2000 block group level models run for Black Non-Hispanic mothers. The group in which low gain had the smallest influence was Hispanic mothers. Amongst Hispanic mothers the contribution of low weight gain was an increased odds of 1.31 of having a low birth weight baby. Gain was only slightly affected by the use of per capita income as a group level variable, slightly decreasing it influence. This suggests the potential for variation across different income groups, which were not included in this research. Therefore, it should be noted that the inclusion of individual-level income variables would further affect the influence of gain on the outcome.

Excess gain status among all models contributed a protective influence to the overall likelihood of having a low birth weight baby. The odds ratios for excess gain ranged from 0.43 to 0.36. Excess gain was less protective among Black Non-Hispanic mothers.

Marital status

The marital status of the mother was a smaller overall influence on the model. Among White Non-Hispanic mothers the influence of being in a not marred category was the strongest. The odds ratio was 1.38 for White Non-Hispanic mothers with little variation for each of the group level predictors. Among Black-Non Hispanic mothers the effect was less pronounced with the highest odds ratio being 1.22.

Age

Age of the mother showed a somewhat moderate influence on the overall model. A mother in the age category of 35+ had a moderate influence on the model (odds ratio of 1.40-1.35. This influence was strongest amongst Hispanic mothers and weakest amongst Black Non-Hispanic mothers. A mother younger than 18 years had a comparable influence on the overall model with odds ratios ranging from 1.4 to 1.38. The strongest influence was seen amongst Hispanic mothers and the weakest amongst Black Non-Hispanic mothers.

Gender of Baby

The gender of the baby had the least influence on the models. The odds ratio ranged from 1.18-1.11. The odds ratio of 1.18 was seen in the complete 2000 model. The smallest influence was seen in Hispanic mothers (odds ratio =1.11). There was little variation in the influence of gender when compared across models run for each of the group level variables.

CHAPTER FIVE

DISCUSSION

Discussion and Interpretation of Results: Summary of Findings

A total of 66,429 low birth weight, singleton babies were born during the study period of 1992-1998. Thus, singleton low birth weight births represent 6% of all singleton births in the State of Florida during this period. This is close to the nationally cited figure for all races of 6.9% of live births. For white non-Hispanics the percent of low birth weight babies was 5% for the study period. Black Non-Hispanics low birth weight outcomes were 10.7% of live births. Additionally, among Hispanics in the sample 5.3% of live singleton births were low birth weight.

The results of the multilevel model for deprived versus non-deprived block groups, after adjusting for individual-level factors, showed a small association between living in a deprived neighborhood and low birth weight outcomes. What the models do not agree on is the measure of deprivation. Some models showed stronger associations between low birth weight and deprivation when deprivation was measured as a single variable, rather than the constructed deprivation index.

Women living in a deprived neighborhood showed an odds ratio 1.08. This corresponds to a 1.08 times increase of having a low birth weight outcome in a deprived neighborhood. However, four of the six variables that comprise the deprivation index showed a larger increased odds of a low birth weight outcome than the constructed deprivation index. The z-score measures of poverty, low educational attainment, unemployment and low per capita income all had odds ratios larger than the 2000 deprivation index (see Appendix A, Table A.1 for values).

Among White Non-Hispanics the odds ratio increased to a 1.16 times increase. Among Black Non-Hispanics the odds increase 1.04 times and for Hispanic women the deprivation index had a 1.12 times increase in the odds of a low birth outcome. The differences seen across ethnic groups may be due to some variable not measured in this study.

The individual variables that make up the deprivation index were used as group- level fixed coefficients to compare the efficacy of using a pre-defined measure of deprivation versus a constructed measure. Of these variables the z-score for per capita income from the 2000 census showed the strongest association with low birth weight outcomes in the overall model. This is consistent with the findings of the literature (Pickett and Pearl 2001; Subramanian and Kawachi 2004). The fact that measures of economic deprivation show the strongest relationship to low birth weight births is not surprising particularly because Subramanian and Kawachi (2004) report that income is a strong determinant of health at both the individual level and the aggregate level.

The association between group variables was much weaker among Black non-Hispanics than among White Non-Hispanics and Hispanics. The odds ratio for the z-score of per capita income was 1.07. This may hint at other factors at play in the determination of health outcomes. Residential segregation, access to health services, stress at both the individual level and neighborhood and perceived socioeconomic status may also play an important role. This may be reflected in the decreased efficacy of any of the group level variables in predicting low birth outcomes. It has been widely reported that Black Non-Hispanics report lower perceived socioeconomic status and experience residential segregation at higher rates than White Non-Hispanics and Hispanics (Brown et al. 2004; Krieger and Smith 2004).

Major Findings

The strength and nature of the relationship between material deprivation and low birth weight outcomes in the State of Florida varies among different ethnic groups and with the use of different indicators. The strongest associations are found when per capita income or percent living below poverty z -scores are used as group-level variables. However, these associations are still very small. All group level-variables showed a stronger relationship to low birth weight outcomes among White Non-Hispanic residents of Florida. Conversely, the same variables showed almost no relationship to the outcome in Black Non-Hispanic residents. The constructed deprivation index showed a small association with low birth weight outcomes among all Florida residents (odds = 1.08) with per capita income showing the strongest association.

The findings do not show the same degree of association between deprivation and low birth weight as do the published results in the current literature. In California Pearl et al. (2001) showed no neighborhood association with birth weight among whites. They did however find an association between neighborhood socioeconomic status and birth weight among Black and Asian residents of California. This study found strongest associations between neighborhood indicators of material deprivation and birth weight and White Non-Hispanic residents of Florida when stratifying for race. This inconsistency with findings in the literature may be due to regional confounding and as such, should be researched further.

Application to Theory

The results of this research unfortunately do not add a clear answer to existing theory on neighborhood deprivation and birth weight. Rather, it highlights the need for further research into the development of useful metrics of socioeconomic deprivation in neighborhoods. This research does show a general trend, in which neighborhood or area level measures of deprivation show some association with negative health outcomes. More research needs to be conducted on how best to measure material deprivation and social deprivation and how best to apply this to health outcomes. The multilevel analysis provided a unique framework to examine the role of deprivation and health outcomes, especially low birth weight.

Revision to Theory

Currently there exists no comprehensive or coherent theory regarding the role of group or neighborhood level socioeconomic deprivation. Rather, a milieu of ideas as to potential pathways, and effects of social and material influence on health. This study adds another voice to the research calling for more investigation into the role of contextual effects on health outcomes.

Hills Criteria for a Causal Relationship Between Neighborhood Deprivation and Low Birth Weight Outcomes

In order to understand the causal relationship between neighborhood deprivation and low birth weight outcomes it may be useful to examine the results from the multilevel models and determine whether they meet all of Hill's criteria of causation. Hill's Criteria of Causation is a set of minimum epidemiologic conditions that must be met to establish a causal relationship between an exposure and an outcome. The criteria are temporal relationship, consistency, strength, specificity, dose-response relationship, biologic plausibility coherence and experiment. If all these criteria are met then it can be assumed that there exists a causal relationship between an exposure and an outcome (Hill 1965).

Temporal Relationship

The first criterion that must be met to establish a causal relationship between material deprivation and low birth weight is that of a temporal relationship. For this to be met material deprivation must precede low birth weight. The aforementioned relationship has been the subject of much debate in the literature. It is commonly agreed upon and assumed that high rates of material deprivation do, in fact lead to negative health outcomes. The meta-analysis conducted by Pickett and Pearl (2001) provides good examples of this, as does Subramanian and Kawachi (2004).

However, placing socioeconomic status in the causal pathway can be problematic. Subramanian and Kawachi (2004) note the need for longitudinal studies to more properly address this issue. Most of the studies conducted in this area have been cross-sectional/ecological. There are a myriad of confounding factors that may influence low birth weight (and negative health outcomes in general). Individual level factors that were not measured here or in other studies should be considered. In particular, medical history of the mother should be taken into account. However, due to the private nature of such information it is often difficult to obtain accurate accounts of previous medical history. Additionally, toxic exposures may also be linked to low birth weight. Data regarding doses and duration of toxic exposures are difficult if not impossible to determine (Kiely et al. 1994).

Strength

The second criterion to be met in order to establish a causal relationship between material deprivation and low birth weight is the strength of the association. This was not met in this study. In all models there was little, if any, statistically significant correlation between economic deprivation (as measured by the deprivation index) and low birth weight outcomes. Other researchers have had mixed results. Some have found a significant relationship while others have not (Picket and Pearl 2001; Subramanian and Kawachi 2004). This may be a function of the type of index being used, rather than the actual strength of association. However, until more rigorous methodologies can be developed to construct deprivation indices in the United States this problem will persist.

Specificity

The relationship between material deprivation and low birth weight is not specific, material deprivation may have a number of other harmful effects other than low birth weight. Furthermore, there are a myriad of other risk factors for low birth weight that were not included in this research (see chapter three and the literature review for discussion of risk factors).

Dose-Response Relationship

As of yet, there has been no study, this one included, which can show an increased risk of low birth weight outcomes with an increase in material deprivation. This too may be due to the inability of the deprivation index to properly measure actual neighborhood deprivation. Additionally the lack of any statistically significant relationship between low birth weight variation across neighborhoods precluded any type of dose-response relationship.

Coherence

The findings of this study are fully compatible with existing epidemiologic theory and knowledge. This study found only small group-level effects on low birth weight outcomes. Individual-level outcomes explained all but a small amount of variance seen in the sample and are most commonly reported as having the strongest association with birth weight.

However, as multilevel analysis is a fairly new experimental design in geography and epidemiology little consensus exists in the literature as to the effects of group level measures of deprivation on low birth weight. The findings here seem to be in line with some (Pearl et al. 2001; Reijnveld 2001) and at odds with others (Subramanian and Kawachi 2004; Pearl et al. 2001).

Biologic Plausibility

The research into the pathways in which material deprivation may operate to cause a low birth weight outcome is still very new. Most of the potential pathways have been examined at the individual level. The extent to which group-level material deprivation may influence any health outcome, low birth weight included, has just begun to be examined. There are three proposed pathways in which material deprivation may be linked to negative health outcomes. These are outlined in Subramanian and Kawachi (2004). The first is the so-called *structural pathway*. In this proposed pathway material deprivation could lead to an increase in residential segregation, which in turn, could cause a concentration of poverty and ethnic groups in spatially isolated areas. The second pathway is the social cohesion and collective social pathway.   This pathway uses the concept of social capital, which can be defined as collective value of social networks (Putnam 2000). In this pathway the presence or absence of collective social pathways, commonly referred to as social capital, influence the behaviors and social environment leading to differences in health outcomes. The third pathway is referred to as the policy pathway. In this pathway the implementation of health-related and social policies may further exacerbate the adverse effects of material deprivation. These pathways may work together or independently to influence material deprivation and health outcome (Subramanian and Kawachi 2004). Because of the newly formed hypotheses regarding socioeconomic influences on health outcomes, it may be too early to tell if a biologically plausible path way exists.

Experiment (Experimental Modification)

The study conducted here can, and should be modified to attempt to measure the effects material deprivation has on low birth weight outcomes. This was an ecologic study aimed at determining if variation in low birth weight in the State of Florida could be explained using group-level measures of material deprivation. An alternate study design would be to conduct a long-term longitudinal study. Multilevel analysis will allow for the nesting of individuals within groups within different periods of time. Additionally, opportunities exist for researchers to study the effects change in socioeconomic status has on health outcomes. For example, an area with a large number of recent lay-offs or areas where certain social programs have seen funding decreases would all serve as a good starting point in experimentally understanding the role socioeconomic deprivation has on a community. An alternative potential modification of this study would be to adjust for regional confounding by adding another level (3 level model) to the current model. The structure of this three level model would be individuals nested within census divisions, nested within regions. Such studies have been conducted on overall health assessment but none have been conducted on birth weight outcomes (Subramanian and Kawachi 2004). Also, the exploration of alternative indices of deprivation and residential segregation may further shed light on the group-level effects on birth weight.

CHAPTER SIX

CONCLUSIONS

Consideration of Alternative Explanations

There are numerous alternative explanations to the findings of this study that there is only a minor group level influence of deprivation on low birth weight. The first may be that there is actually a difference, however, multilevel models as they exist now, or were executed in this study are not yet sufficient in explaining group-level variation. Additionally, some limitations of the study may have also contributed to the results (see limitations). The effects of income and deprivation on Florida residents seem to contradict some of the findings in the multilevel literature (Pearl et al. 2001). This quite possibly could be due to regional differences in population, residential segregation, or other types of regional confounding (more rural vs. urban areas, for example). The results here show a moderate effect of group-level variables on birth weight. However, this study did not adjust for individual income or medical risks. It is possible that after adjusting for these factors the group level influences may altogether disappear.

Consistency with Literature

The findings somewhat contrast with published results in the literature. In California Pearl et al. (2001) showed no neighborhood association with birth weight among whites. They did however find an association between neighborhood socioeconomic status and birth weight among Black and Asian residents of California. In this study the strongest association was amongst white residents. This difference may be due to regional confounding. Which is to say that there may be “clusters” of states within larger regions that are more similar in the distribution and effects of contextual variables on health outcomes than other regions. A potential modification of this study would be to adjust for regional confounding by adding another level (3 level model) to the current model. The structure of this three level model would be individuals nested within census divisions, nested within regions. Such studies have been conducted on overall health assessment but none have been conducted on birth weight outcomes (Subramanian and Kawachi 2004).

The findings of this study are consistent with some of the findings in the literature. There have been mixed results in the use of multilevel modeling of health outcomes in which an index or measure of deprivation is used. See *Discussion Chapter 5* and Subramanian and Kawachi (2004) for a complete discussion of income related deprivation and health outcomes. Most studies that have been able to demonstrate an influence of group-level deprivation have used State, County or MSA for the group. Smaller scale studies, with the exception of Diez-Roux et al. 2001, have had similar results. Moreover, Reijnevled (2001) has proposed that some, if not all, of the studies that have found a significant association between socioeconomic environment and health outcomes have incompletely adjusted for individual level socioeconomic factors, which could be said about this study. Additionally, of those studies that have shown a positive association only show modest effects on health outcomes and, due to issues of statistical power, are at risk of overestimation of the effects. (Reijnevled, 2001).

Limitations

The lack of utility of the Deprivation index in predicting geographic variation in low birth weight outcomes may be the result of any of several factors. The deprivation index may have different utility in rural versus urban areas. Jordan et al. (2004) report differences in the predictive utility of multiple deprivation indices in urban versus rural areas. This was not examined in this study. Perhaps the inclusion of a group level variable indicating whether the block group is in a rural area or an urban area. The inability of the individual factors comprising the deprivation index to predict low birth weight variability may also lend credence to this suggestion.

Additionally, the boundaries constructed for the purpose of this study were taken directly from the United States Census Bureau. These boundaries are by no means a complete representation of an individual's social and or economic environment. Carefully conceptualizing the idea of social environment, neighborhood and social capital may provide a better approximation of an individual's social and economic group membership. Such a study was beyond the scope of this research. Moreover, the inclusion of a measure of residential segregation may also provide some utility in this area. Perhaps a model of individual-level variables and a group level measure of residential segregation or a combination of residential segregation and material/social deprivation may be of more use.

The deprivation index itself may be flawed. The index is part of the social indicators used by the National Association of Planning Councils. It was developed by Andrulius (2004) and was designed for the MSA level, not the census block group level. This may explain some of the lack of explanatory power of the index. Additionally, crime rates, considered a source of maternal stress by many researchers could not be included in this index while it was in. The reason for the lack of inclusion was that crime data in the US is only available at the MSA level for some areas. Additionally, the factors comprising the deprivation index were measured for 1990 and 2000. The sample was for 1992-1998. Measurements taken for each year would be more accurate representations of the conditions at the time of each birth.

Recent literature suggests that an individual's *perceived* deprivation may be more important than statistical measures of deprivation. Studies in which individuals self report negative health outcomes and perceived social and material deprivation those individuals with a higher frequency of reported negative health outcomes also have a perception of more economic and social deprivation (Brown et al.. 2004; Subramanian and Kawachi 2004; Picket and Pearl 2001).

Another limitation is a difference in the modeling or modeling errors. Many models in the literature use different methods of statistical analysis. For example most studies use marginal models (Subramanian and Kawachi 2004). Marginal models ignore the variance structure when estimating the fixed effect of exposure. This is erroneous in that the models are specifically ignoring variability information, which is the purpose of multilevel modeling. This study was not a marginal model and this may account for differences between the results found here and in the literature. Another alternate explanation is that the random coefficients associated with the area (block groups and census tracts) were not able to be included. This is a common error in multilevel analysis due to software and intensive computation. The random coefficient of interest in this study is the extent of unconditional variation of block group-attributable (or census tract) low birth weight outcomes. This will have an effect on the overall variance of the model.

Additionally, this study utilized MLwiN, a statistical package designed exclusively for developing multilevel models. The software is relatively new and different to existing software packages. Therefore, there is little to compare it to as far as ease of use and accuracy of results. The size of the data set seemed to slow the program and render some of its functions unusable. While this did not actually preclude the statistical assessment of the sample, it put time constraints on those that were run. The large sample size and hierarchical nature of the data created limitations as to what could be modeled. For example, categorical variables with more than 3 categories could not be included in the model due to the large size of the data. This was an issue as several of the categorical variables initially considered for the model could not be included and as such were converted to continuous variables. Little in the literature exists regarding multilevel logistic regression analysis. Therefore, more sophisticated models may be necessary to truly model the relationship between the outcome and the variables.

Lastly, this model was not able to adjust for individual level income, or medical-risks predating and during pregnancy. This surely would have an effect on the outcomes of these models. Specifically, with the inclusion of these variables the effect of group level variables would decrease.

Strengths

The main strength of this study lies in the fact that it treats low birth weight as an outcome that varies spatially. While the ability of the study to detect significant spatial variation was unsuccessful, the methodology did not ignore the geographic component of the outcome and at the same time it took into account the individual level factors that influence the outcome. Diez-Roux (2000) finds that a multilevel methodology is best suited to deal with geographic variability while controlling for individual level factors. Additionally multilevel models are particularly well suited for avoiding the ecological fallacy common in studies of geographic variability. Another strength of this study was the sample size. Rarely is such a large sample size available to a researcher. With the addition of a more accurate deprivation index the full potential of this sample can be realized.

Geographic/Public Health Implications

The geographic implications of the findings of this research are the need for geography to adequately address issues of group (neighborhood) boundaries and membership. Geography is uniquely positioned to examine the boundaries of an individual's physical neighborhood as well as their social group. The contextual nature of multilevel analysis makes it a good quantitative methodology to complement the qualitative research of contextual effects. Through the examination of the flow of social capital and what makes a neighborhood, geography can add a much-needed theoretical component to multilevel modeling. Additionally, spatial examination of geographically-attributable variance in health outcomes is the key to a successful multilevel analysis of health and place and as such almost requires a geographic perspective.

The public health implications of this research are that more attention should be paid to group level influences and geographic variance of health outcomes. This research has shown some mild effects of context on birth weight. The differences between this study and others definitely call for more inquiry into contextual health effects. However, the traditionally individualistic nature of epidemiology should not be fully abandoned. As illustrated by this research, individual-level variables still comprise the majority of negative health outcome risk factors.

Moreover, this study has further bolstered the findings of numerous other public health researchers regarding low birth weight outcomes. The individual factors of smoking, Black Non-Hispanic ethnicity, primiparity and age of the mother were shown to have significant associations with low birth weight outcomes that are in agreement with the majority of published literature.

This research partially supports the hypothesis that, after adjusting for individual level variables, the odds of having a low birth weight child are higher for a mother living in a neighborhood with a high deprivation index score than a mother living in a neighborhood with a low deprivation index score. The increased odds were not particularly strong however, the findings of this research are in the same direction as others in the literature. Additionally, this research was unable to determine if a significant portion of the spatial variation of low birth weight outcomes in the State of Florida is due to neighborhood effects.

This research has supported some of the literature, particularly concerning the effect of neighborhood per capita income on birth weight. However, it is partially contradictory to some. Pearl et al. (2001) found a significant relationship between neighborhood socioeconomic variables and birth weight in among Black Non-Hispanics in California. This study of Florida residents found no such relationship, in fact, the strongest association between neighborhood-level indicators and birth weight was among White Non-Hispanics. This suggests more research into the variability of socioeconomic indicators is necessary. Moreover, research into differences in community structures, definitions of communities and social group in different geographic regions will also prove helpful in understanding the influence of socioeconomic context on health outcomes.

REFERENCES

Ahern, J., Pickett, K.E., Selvin, S., Abrams, B., 2003 Preterm birth among African American and white women: a multilevel analysis of socioeconomic characteristics and cigarette smoking. *J Epidemiol Community Health* 57:606–611

American Academy of Pediatrics, American College of Obstetricians and Gynecologists. 1988. Standard terminology for reporting of reproductive health statistics in the United States. Public Health Rep 103:464–71.

Anderson, R. T., P. Sorlie, E. Backlund, N. Johnson, and G. A. Kaplan. 1997. "Mortality Effects of Community Socioeconomic Status." *Epidemiology* 8:42–7.

Andrulius, D.P. , Reid, H.M., and Duchon, L. 2004. *Quality of life in the nation's 100 largest cities and their suburbs: New and continuing challenges for improving health and well being.* SUNY Downstate Medical Center.

Baker D., W., Parker, R.M., Williams, M, V. et al 1998. Health literacy and the risk of hospital admission. *J Gen Intern Med.* 13:791-798

Backlund, E., Sorlie, P.D., Johnson N.J., 1996. The shape of the relationship between income and mortality in the United States: evidence from the National Longitudinal Mortality Study. *Ann Epidemol.* 6:12-20

Barker, D.J.P., 1992. Fetal and infant origins of adult onset diseases. *British Medical Journal* p341

Berendes H.W., Forman MR. Delayed childbearing: trends and consequences. In: Kiely M, ed. Reproductive and perinatal epidemiology. Boca Raton, Florida: CRC Press, 1991.

Brown, A.F., Ettner, S., Piette, J. Weinberger, M., Gregg, E., et al.. 2004. Socioeconomic position and health among persons with Diabetes Mellitus: Conceptual framework and review of the literature. *Epidemiologic Reviews* 26: 63-77

Bostock L. 2001. Pathways of disadvantage? Walking as a mode of transport among low-income mothers. *Health Soc Care Community* 9:11-18.

Carstaris, V., 2000. *in* Elliott, P., Wakefiled, J., Best, N., and Briggs, D. *Eds.* 2001. *Spatial Epidemiology.* Oxford University Press.

Cassel, J. 1964. Social science theory as a source of hypotheses in epidemiologic research. *Am J Public Health*. 54: 1482-1488

Couregeau, Daniel in: *Courgeau, Daniel (ed). 2003 Methodology and Epistemology of Multilevel Analysis: Approaches from Different Social Sciences*.
Dordrecht/Boston/London; Kluwer Academic Publishers.

Diez Roux, A.V. 2004 The Study of Group-Level Factors in Epidemiology: Rethinking Variables, Study Designs, and Analytical Approaches
Epidemiol Rev 26: 104-111; doi:10.1093/epirev/mxh006

Diez-Roux, A.V., 2003 Potentialities and limitations of multilevel analysis in public health and epidemiology. In: *Courgeau, Daniel (ed). 2003 Methodology and Epistemology of Multilevel Analysis: Approaches from Different Social Sciences*.
Dordrecht/Boston/London; Kluwer Academic Publishers.

Diez-Roux, A.V., Merkin, S.S., Arnett, D., et al. 2001 Neighborhood of residence and incidence of coronary heart disease. *New England Journal of Medicine*, 345, 99-106.

Diez-Roux, A. 2001. Investigating neighborhood and area effects on health. *Am J Public Health* 19 (11):1783-1789

Diez-Roux, A, 2000: Multilevel Analysis in Public Health Research. *Ann. Rev. Public Health.* 21: 171-92

Diez-Roux 1998 American Journal of Public Health
Bringing Context back into epidemiology: variables and fallacies in multilevel analysis
Vol 88, Issue2 2-216-222

Diez Roux, A. V., F. J. Nieto, C. Muntaner, H. A. Tyroler, G. W. Comstock, E. Shahar, L. S. Cooper, R. L. Watson, and M. Szklo. 1997. “Neighborhood Environments and Coronary Heart Disease: A Multilevel Analysis.” *American Journal of Epidemiology* 146(1):48–63.

Duncan, C., Jones, K., and Moon, G., 1996: Health-related behavior in context: A multilevel modeling approach. *Soc. Sci. Med.* **42**(6); 817-830.

Dovey, K. 1985. An ecology of place and placemaking. Structures, process, knots of meaning. *In* Dovey, K., Downton, P., and Missingham, G., eds *Place and Placemaking, Proceedings of the PAPER 85 Conference.* Melbourne, 19-22 June 1985. Faculty of Architecture and Building. Royal Melbourne Institute of Technology. Melbourne Australia.

Epstein, A.M., Taylor, W., C., Seage, G., R., 1985. Effects of patients' socioeconomic status and physicians' training and practice on patient-doctor communication. *Am J Med.* 7:101-106.

Fiscella, K., Goodwin. M., A., Stange, K.,C. 2002. Does patient educational level affect office visits to family physicians? *J Natl Medical Assoc.* 94:157-165.

Gazamararian, J., A., Parker, R., M., Williams. M.,W., et al. 1999 Reading Skills and family planning knowledge and practices in a low-income managed-care population. *Obstet Gynecol.* 93:239-244

Geronimus AT, Korenman S. 1993. Maternal youth or family background? On the health disadvantages of infants with teenage mothers. Am J Epidemiol. 137:213–25.

Giddens, A. 1984. *The Constitution of Society: Outline of the Theory of Structuration*. Berkeley, University of California Press.

Goldstein H., Rasbash J., 1996. Improved approximations for multilevel models with binary responses*. J R Stat Soc* 159: 505–13.

Greenland, S., 2001: Ecologic versus individual-level sources of bias in ecologic estimates of contextual health effects*. Int. J. Epidemiol*. 30: 1343-1350

Haan M., Kaplan G.A., Camacho, T., 1987. Poverty and health: perspectives evidence from the Alameda County Study. *Am J of Epidemiol.* 125:989-998

Hack, M., Taylor, G., Klein, N., et al.. 1994 School-age outcomes in children with birth weights under 750 g. *New England Journal of Medicine* 331:753-59.

Harding, J.E. 2001. The nutritional basis of the fetal origins of adult disease. *Int J Epidemiology* 30(1) 15-23.

Hawe, P., 1998. Making sense of context-level influences on health. Editorial in *Am J Epidemiol.* 146:1-4.

Hox, J.J., 1995 *Applied Multilevel Analysis*. TT-Publikaties-Amsterdam.

Institute of Medicine, Committee to Study the Prevention of Low Birth Weight. 1985. *Preventing low birth weight*. Washington, DC: National Academy Press

Jarman, B. 1984. Underprivileged areas: validation and distribution of scores. *Brit Med J* 289: 1587-1592.

Jones, K. and Duncan, C. 1998. Modeling context and heterogeneity: Applying multilevel models. In E. Scarbrough and E. Tanenbaum (eds.), *Research Strategies in the Social Sciences*. Oxford University Press

Krieger, N., D. L. Rowley, A. A. Herman, B. Avery, and M. T. Phillips. 1993. "Racism, Sexism and Social Class: Implications for Studies of Health, Disease, and Well-Being." *American Journal of Preventive Medicine* 9(suppl 2):82–122.

Kessel SS, Kleinman JC. Koontz AM, Hogue CJR, Berendes HW. Racial differences in pregnancy outcomes. *Clin Perinatol* 1988;15:745–54.

Kiely, J.L., Yu, S., Rowley, D.L., 1994. Low birth weight and intrauterine growth retardation. *In: From Data to Action; CDC's Public Health Surveillance for Women, Infants and Children. Atlanta.*

Kline J, Stein Z, Susser M. Conception to birth: epidemiology of prenatal development. New York: Oxford University Press, 1989.

Kleinman, J., and Kessel, S. 1987.Racial differences in low birth weight. *New England Journal of Medicine* 317:749-53.

Kramer MS. Determinants of low birth weight: methodological assessment and meta-analysis. Bull World Health Organ 1987;65:663–737.

Kreiger, N., Williams, D.R., Moss, N.E. 1997 Measuring social class in US public health research: concepts, methodologies, and guidelines, *Annu Rev Public Health* 18:341-378.

Kuh D, and Ben-Shlomo, Y. 1997., *A Life course approach to chronic disease epidemiology. New York: Oxford University Press*. p.317

Kuhn, T., 1962 *The Structure of Scientific Revolutions.* University of Chicago Press.pp 211

Larzfeld, P.F. and Menzel, H., 1961. *On the relation between individual and collective properties.* In: A. Etzioni (ed.) *Complex Organizations: A Sociological Reader.* New York: Holt, Reinhardt & Winston.

LeClere, F. B., R. G. Rogers, and K. D. Peters. 1998. "Neighborhood Social Context and Racial Differences in Women's Heart Disease Mortality." *Journal of Health Social Behavior* 39:91–107

Lynch, J. W., and G. A. Kaplan. 2000. Socioeconomic Position. In *Social Epidemiology*, edited by L. F. Berkman and I. Kawachi, 13–35. New York: Oxford University Press

Lynch, J.W., Kaplan, G.A., Shema, S.J. 1997 Cumulative impact of sustained economic hardship on physical, cognitive, psychological and social functioning. *N Engl J Med* 1997; 333:1889-1895

Marmot, M. 2002. The influence of income on health: views of an epidemiologist. Does money really matter? Or is it a marker for something else? *Health Aff (*Millwood) 21:31—46.

Macintyre, S., Maciver, S., and Sooman, A., 1993. Area class and health: should we be focusing on places or people? *Journal of Social Policy* 22:213-234.

Melnikow, J., Paliescheskey, M., Stewart, G., K. 1997. Effect of a transportation incentive on compliance with the first prenatal appointment: a randomized trial. *Obstet Gynecol.* 89:1023-1027.

Morgan M, Chinn S. 1983. ACORN group, social class, and child health. *J Epidemiol Community* Health;37:196–203.

NCHS. Vital statistics of the United States, 1988. Vol. I, natality. Hyattsville, Maryland: US Department of Health and Human Services, Public Health Service, CDC, 1990.

NCHS. Vital statistics of the United States, 2001. Vol. I, natality. Hyattsville, Maryland: US Department of Health and Human Services, Public Health Service, CDC, 2002.

O'Campo, P., X. Xue, M.-C. Wang, and M. O. Caughy. 1997. "Neighborhood Risk Factors for Low Birth weight in Baltimore: A Multilevel Analysis." *American Journal of Public Health* 87(7):1113–8.

O'Donnell, C.R. ,Tharp, R., G., and Wilson, K., 1993. Activity settings as the unity of analysis a theoretical basis for community intervention and development. *American Journal of Public Health.* 86: 678-683

Pearl, M., Braveman, P., and Abrams, B. 2001 The relationship of neighborhood socioeconomic characteristics to birthweight among 5 ethnic groups in California. *Am J Public Health* 19 (11) 1808-1814

Pickett, K., E. and Pearl, M. 2001 Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. *J Epidemiol Community Health.* 55:111-122

Putnam R., D., 2000. *Bowling Alone: The Collapse and Revival of American Community* New York: Simon & Schuster.

Raudenbush, Stephen W. and Sampson, Robert J. (1999). Ecometrics: Toward a Science of Assessing Ecological Settings, with Application to the Systematic Social Observation of Neighborhoods. *Sociological Methodology*, *29*, *1-41.*

Raugh., V.A., Andrews, H.F., and Garfinkel, R.S., 2001. The contribution of maternal age to racial disparities in birthweitght: A multilevel perspective. *Am J Public Health* 19 (11) 1815-1823

Ravelli, G.P., Stein, Z.A., Susser, M.W. 1976. Obesity in young men after famine exposure in utero and early infancy. *New England Journal of Medicine* 295: 349-353

Reader, S. 2001. Detecting and analyzing clusters of low-birth weight incidence using exploratory spatial data analysis. *Geo Journal* 53: 149-159.

Reijneveled, S., A., 2001.Explanations for differences in health outcomes between neighborhoods of varying socioeconomic level. *J Epidemiol Community Health.* 55:847-848

Reijneveled, S., A., 1998. The impact of individual and area characteristics on urban socioeconomic differences in health and smoking. *Int J Epidemiol.* 27:33-40

Rice, N., 2001 Binomial Regression in Leyland, A.H., and Goldstein, H., (eds) *Multilevel Modeling of Health Statistics* John Wiley and Sons, Ltd New York.

Roberts, E. M. 1997. “Neighborhood Social Environments and the Distribution of Low Birthweight in Chicago.” *American Journal of Public Health* 87(4):5970150603

Schur, C., L., Albers, L., A., 1996, Language, sociodemographics and health care us of Hispanic adults. *J Health Care Poor Underserved*. 7:140-158

Shiono, P.H., Klebanoff, M.A., Graubard, B., et al.. 1986. Birth weight among women of different ethnic groups. *Journal of the American Medical Association* 255:48-52.

Shiono, P.H., Klebanoff, M.A., Nugent, R.P., et al.. 1995. The impact of cocaine and marijuana use on low birth weight and preterm birth: A multicenter study. *American Journal of Obstetrics and Gynecology.* 172:19-27.

Smith G., D., Hart, C., Blane, D., et al. 1998. Adverse socioeconomic conditions in childhood and cause specific adult mortality: perspective observational study. *BMJ.* 316:1631-1635.

Stein ZA, Susser M. Intrauterine growth retardation: Epidemiological issues and public health significance. *Semin Perinatol* 1984; 8:5–14.

Subramanian S.V., Kawachi, I. 2004. Income inequality and Health: What have we learned so far? *Epidemiologic Reviews* 26: 78-91

Swanborn, P.G., 1981. *Methods of Social Research.* Amsterdam/Meppel: Boom.

Szklo, M., and Nieto, F. J., 2000. *Epidemiology: Beyond the Basics.* Aspen Publishers, Gaithersburg. Md.

Teaching Resources and Materials for Social Scientists (TRAMSS webpage) 1999 http://tramss.data-archive.au.uk

Takano, T., Nakamura, K., 2001. An analysis of health levels and various indicators of urban environments for Healthy Cities projects. *J Epidemiol Comm Health.* 55:263-270.

Terry, M.B., and Susser, E., 2001. Commentary: The impact of fetal and infant exposures along the life course. *Int J Epidemiology* 30 (1):95-96.

Townsend, P. Phillimore, P. and Beattie, A. (1988). Health and deprivation: inequality and the North. London*, Croom Helm.*

Vassen, N., Joop, A.J., Heutinik, P., Hofman, A., Lamberts, S.W.J., Oostra, B.A., Pols, H.A.P., van Duijn, C.M. 2002. Association between genetic variation in the gene for insulin-like growth factor-I and low birth weight. *Lancet* 359: 1036-1037

Wilcox A, Russell I. Why small black infants have a lower mortality rate than small white infants: the case for population-specific standards for birth weight*. J Pediatr* 1990;116:7–10.

Williamson, D., Fast, J., E., 1989 Poverty and medical treatment: when public policy compromises accessibility. *Can J. Public Health.* 89:120-124.

Williams, M., V., Baker, D., W., Parker, R., M., et al. 1998. Relationship of functional health literacy to patients' knowledge of their chronic disease: a study of patients with hypertension and diabetes. *Arch Intern Med.* 158:166-172

Ylppö A. 1919 Zur physiologie, klinik, zum schicksal der frühgeborenen. Zeitschrift für kinderheilkunde 24:1–110.

Appendices

Appendix A: Multilevel Model Results Tables

Table A.1 Results of Complete Multilevel Model For Year 2000 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.22	2.17	2.22	2.18	2.16	2.18	2.22
Not Married	1.29	1.29	1.40	1.29	1.17	1.29	1.29
Female	1.18	1.18	1.17	1.18	1.18	1.18	1.18
Black Non-Hispanic	2.02	1.87	2.02	2.02	1.87	1.91	2.02
Hispanic	1.17	1.16	1.17	1.16	1.16	1.16	1.16
Younger than 18 yrs	1.13	1.13	1.12	1.13	1.13	1.13	1.13
Older than 34 yrs	1.38	1.38	1.38	1.38	1.38	1.38	1.38
Primiparous	1.52	1.52	1.52	1.52	1.52	1.52	1.52
Low Gain	1.27	1.27	1.27	1.27	1.27	1.27	1.27
Excess Gain	0.36	0.38	0.36	0.38	0.38	0.36	0.39
Group Variable							
2000 Deprivation Index	1.08	***	***	***	***	***	***
2000 Poverty	***	1.21	***	***	***	***	***
2000 No Vehicle	***	***	1.07	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.15	***	***	***
2000 Per Capita Income	***	***	***	***	1.27	***	***
2000 Unemployment	***	***	***	***	***	1.11	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.04

Appendix A (Continued)

Table A.2 Results of Complete Multilevel Model For Year 1990 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	Poverty	Vehicle Ownership	Educational Attainment	Per Capita Income	Unemployment	Linguistic Isolation
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.17	2.20	2.22	2.17	2.16	2.17	2.22
Not Married	1.28	1.29	1.30	1.52	1.29	1.29	1.29
Female	1.17	1.16	1.17	1.11	1.18	1.17	1.18
Black Non-Hispanic	1.92	1.85	1.96	2.02	2.02	1.92	2.02
Hispanic	1.13	1.12	1.13	1.16	1.16	1.13	1.16
Younger than 18 yrs	1.13	1.12	1.13	1.13	1.13	1.13	1.13
Older than 34 yrs	1.38	1.36	1.39	1.38	1.38	1.38	1.38
Primiparous	1.60	1.61	1.61	1.52	1.52	1.60	1.52
Low Gain	1.26	1.26	1.26	1.27	1.27	1.26	1.27
Excess Gain	0.38	0.39	0.38	0.38	0.38	0.38	0.38
Group Variable							
1990 Deprivation Index	1.06	***	***	***	***	***	***
1990 Poverty	***	1.05	***	***	***	***	***
1990 No Vehicle	***	***	1.03	***	***	***	***
1990 Low Educational Attainment	***	***	***	1.08	***	***	***
1990 Per Capita Income	***	***	***	***	1.13	***	***
1990 Unemployment	***	***	***	***	***	1.05	***
1990 Linguistic Isolation	***	***	***	***	***	***	1.02

Appendix A (Continued)

Table A.3 Results of Multilevel Model For White Non-Hispanic Mothers Year 2000 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables

	Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Individual Variable	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.24	2.23	2.24	2.24	2.22	2.24	2.24
Not Married	1.37	1.38	1.38	1.38	1.38	1.38	1.38
Female	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Younger than 18 yrs	1.32	1.32	1.33	1.33	1.32	1.32	1.33
Older than 34 yrs	1.39	1.38	1.38	1.38	1.40	1.38	1.38
Primiparous	1.77	1.77	1.77	1.77	1.77	1.77	1.77
Low Gain	1.80	1.77	1.80	1.80	1.80	1.80	1.80
Excess Gain	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Group Variable							
2000 Deprivation Index	1.16	***	***	***	***	***	***
2000 Poverty	***	1.08	***	***	***	***	***
2000 No Vehicle	***	***	1.08	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.13	***	***	***
2000 Per Capita Income	***	***	***	***	1.12	***	***
2000 Unemployment	***	***	***	***	***	1.10	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.10

Appendix A (Continued)

Table A.4 Results of Multilevel Model For White Non-Hispanic Mothers Year 1990 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.23	2.23	2.24	2.23	2.23	2.24	2.25
Not Married	1.37	1.38	1.39	1.38	1.38	1.39	1.38
Female	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Younger than 18 yrs	1.32	1.32	1.33	1.32	1.32	1.33	1.33
Older than 34 yrs	1.39	1.39	1.38	1.39	1.39	1.38	1.38
Primiparous	1.77	1.77	1.77	1.77	1.77	1.76	1.77
Low Gain	1.80	1.80	1.81	1.80	1.80	1.81	1.80
Excess Gain	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Group Variable							
1990 Deprivation Index	1.09	***	***	***	***	***	***
1990 Poverty	***	1.07	***	***	***	***	***
1990 No Vehicle	***	***	1.27	***	***	***	***
1990 Low Educational Attainment	***	***	***	1.04	***	***	***
1990 Per Capita Income	***	***	***	***	1.07	***	***
1990 Unemployment	***	***	***	***	***	1.08	***
1990 Linguistic Isolation	***	***	***	***	***	***	1.18

Appendix A (Continued)

Table A.5 Results of Multilevel Model For Black Non-Hispanic Mothers Year 2000 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.09	2.09	2.08	2.09	2.09	2.09	2.08
Not Married	1.22	1.22	1.23	1.23	1.23	1.22	1.22
Female	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Younger than 18 yrs	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Older than 34 yrs	1.27	1.15	1.28	1.28	1.28	1.28	1.28
Primiparous	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Low Gain	1.92	1.92	0.19	1.94	1.92	1.93	1.93
Excess Gain	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Group Variable							
2000 Deprivation Index	1.04	***	***	***	***	***	***
2000 Poverty	***	1.12	***	***	***	***	***
2000 No Vehicle	***	***	1.04	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.02	***	***	***
2000 Per Capita Income	***	***	***	***	1.10	***	***
2000 Unemployment	***	***	***	***	***	1.03	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.13

Appendix A (Continued)

Table A.6 Results of Multilevel Model For Black Non-Hispanic Mothers Year 1990 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables

	Full Model Deprivation Index	Poverty	Vehicle Ownership	Educational Attainment	Per Capita Income	Unemployment	Linguistic Isolation
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.09	2.08	2.09	2.09	2.08	2.09	2.09
Not Married	1.23	1.23	1.22	1.22	1.22	1.22	1.23
Female	1.21	1.21	1.21	1.21	1.22	1.22	1.22
Younger than 18 yrs	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Older than 34 yrs	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Primiparous	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Low Gain	1.93	1.93	1.93	1.92	1.92	1.92	1.93
Excess Gain	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Group Variable							
1990 Deprivation Index	1.02	***	***	***	***	***	***
1990 Poverty	***	1.01	***	***	***	***	***
1990 No Vehicle	***	***	1.05	***	***	***	***
1990 Low Educational Attainment	***	***	***	1.04	***	***	***
1990 Per Capita Income	***	***	***	***	1.04	***	***
1990 Unemployment	***	***	***	***	***	1.04	***
1990 Linguistic Isolation	***	***	***	***	***	***	1.04

Appendix A (Continued)

Table A.7 Results of Multilevel Model For Hispanic Mothers Year 2000 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.16	2.15	2.15	2.16	2.15	2.15	2.15
Not Married	1.27	1.27	1.27	1.27	1.28	1.29	1.27
Female	1.11	1.11	1.11	1.18	1.18	1.18	1.18
Younger than 18 yrs	1.35	1.35	1.35	1.13	1.13	1.13	1.13
Older than 34 yrs	1.41	1.15	1.41	1.38	1.38	1.38	1.38
Primiparous	1.64	1.64	1.64	1.64	1.64	1.63	1.64
Low Gain	1.32	1.32	1.32	1.32	1.32	1.33	1.32
Excess Gain	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Group Variable							
2000 Deprivation Index	1.12	***	***	***	***	***	***
2000 Poverty	***	1.09	***	***	***	***	***
2000 No Vehicle	***	***	1.12	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.06	***	***	***
2000 Per Capita Income	***	***	***	***	1.10	***	***
2000 Unemployment	***	***	***	***	***	1.28	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.11

Appendix A (Continued)

Table A.*8 *Results of Multilevel Model For Hispanic Mothers Year 1990 Census Block Groups Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.15	2.16	2.15	2.16	2.16	2.15	2.15
Not Married	1.27	1.27	1.27	1.27	1.27	1.27	1.26
Female	1.11	1.11	1.11	1.11	1.11	1.11	1.11
Younger than 18 yrs	1.35	1.35	1.35	1.35	1.35	1.35	1.35
Older than 34 yrs	1.41	1.41	1.41	1.41	1.41	1.41	1.41
Primiparous	1.64	1.64	1.63	1.64	1.64	1.64	1.64
Low Gain	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Excess Gain	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Group Variable							
1990 Deprivation Index	1.06	***	***	***	***	***	***
1990 Poverty	***	1.05	***	***	***	***	***
1990 No Vehicle	***	***	1.07	***	***	***	***
1990 Low Educational Attainment	***	***	***	1.03	***	***	***
1990 Per Capita Income	***	***	***	***	1.05	***	***
1990 Unemployment	***	***	***	***	***	1.07	***
1990 Linguistic Isolation	***	***	***	***	***	***	1.08

Appendix A (Continued)

Table A.9 Results of Complete Multilevel Model For Year 2000 Census Tracts Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	Poverty	Vehicle Ownership	Educational Attainment	Per Capita Income	Unemployment	Linguistic Isolation
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.18	2.18	2.18	2.18	2.18	2.18	2.18
Not Married	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Female	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Black Non-Hispanic	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Hispanic	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Younger than 18 yrs	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Older than 34 yrs	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Primiparous	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Low Gain	1.27	1.27	1.27	1.27	1.27	1.27	1.27
Excess Gain	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Group Variable							
2000 Deprivation Index	1.07	***	***	***	***	***	***
2000 Poverty	***	1.19	***	***	***	***	***
2000 No Vehicle	***	***	1.05	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.13	***	***	***
2000 Per Capita Income	***	***	***	***	1.02		***
2000 Unemployment	***	***	***	***	***	1.10	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.03

Appendix A (Continued)

Table A.10 Results of Complete Multilevel Models Year 1990 Census Tracts Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.18	2.18	2.18	2.18	2.18	2.18	2.18
Not Married	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Female	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Black Non-Hispanic	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Hispanic	1.13	1.13	1.13	1.13	1.13	1.13	1.13
Younger than 18 yrs	1.12	1.12	1.12	1.12	1.12	1.12	1.12
Older than 34 yrs	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Primiparous	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Low Gain	1.27	1.27	1.27	1.27	1.27	1.27	1.27
Excess Gain	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Group Variable							
1990 Deprivation Index	1.07	***	***	***	***	***	***
1990 Poverty	***	1.19	***	***	***	***	***
1990 No Vehicle	***	***	1.05	***	***	***	***
1990 Low Educational Attainment	***	***	***	1.13	***	***	***
1990 Per Capita Income	***	***	***	***	1.02	***	***
1990 Unemployment	***	***	***	***	***	1.10	***
1990 Linguistic Isolation	***	***	***	***	***	***	1.03

Appendix A (Continued)

Table A.11 Results of Multilevel Model For White Non-Hispanic Mothers Year 2000 Census Tracts Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.20	2.19	2.20	2.20	2.18	2.20	2.20
Not Married	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Female	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Younger than 18 yrs	1.24	1.24	1.24	1.24	1.24	1.24	1.24
Older than 34 yrs	1.36	1.36	1.36	1.36	1.37	1.36	1.36
Primiparous	1.74	1.74	1.74	1.74	1.74	1.74	1.74
Low Gain	1.94	1.91	1.95	1.95	1.94	1.95	1.95
Excess Gain	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Group Variable							
2000 Deprivation Index	1.11	***	***	***	***	***	***
2000 Poverty	***	1.05	***	***	***	***	***
2000 No Vehicle	***	***	1.06	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.09		***	***
2000 Per Capita Income	***	***	***	***	1.08	***	***
2000 Unemployment	***	***	***	***	***	1.06	
2000 Linguistic Isolation	***	***	***	***	***	***	1.07

Appendix A (Continued)

Table A.12 Results of Multilevel Model For White Non-Hispanic Mothers Year 1990 Census Tracts Showing Odds Ratios For Individual and Group Level Variables

	Full Model Deprivation Index	Poverty	Vehicle Ownership	Educational Attainment	Per Capita Income	Unemployment	Linguistic Isolation
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.19	2.19	2.20	2.19	2.20	2.20	2.21
Not Married	1.36	1.36	1.37	1.36	1.37	1.37	1.36
Female	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Younger than 18 yrs	1.24	1.24	1.24	1.23	1.24	1.24	1.24
Older than 34 yrs	1.36	1.36	1.36	1.36	1.35	1.35	1.36
Primiparous	1.74	1.74	1.74	1.74	1.74	1.74	1.74
Low Gain	1.94	1.94	1.95	1.94	1.95	1.95	1.95
Excess Gain	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Group Variable							
2000 Deprivation Index	1.09	***	***	***	***	***	***
2000 Poverty	***	1.04	***	***	***	***	***
2000 No Vehicle	***	***	1.17	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.07	***	***	***
2000 Per Capita Income	***	***	***	***	1.05	***	***
2000 Unemployment	***	***	***	***	***	1.05	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.11

Appendix A (Continued)

Table A.13 Results of Multilevel Model For Black Non-Hispanic Mothers Year 2000 Census Tracts Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.06	2.05	2.05	2.05	2.06	2.05	2.05
Not Married	1.21	1.21	1.21	1.22	1.22	1.21	1.22
Female	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Black Non-Hispanic	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Hispanic	1.26	1.26	1.26	1.26	1.26	1.26	1.27
Younger than 18 yrs	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Older than 34 yrs	2.09	2.09	2.09	2.12	2.10	2.10	2.11
Primiparous	0.82	0.14	0.82	0.82	0.82	0.82	0.82
Low Gain	1.94	1.91	1.95	1.95	1.94	1.95	1.95
Excess Gain	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Group Variable							
2000 Deprivation Index	1.03	***	***	***	***	***	***
2000 Poverty	***	1.05	***	***	***	***	***
2000 No Vehicle	***	***	1.05	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.01	***	***	***
2000 Per Capita Income	***	***	***	***	1.04	***	***
2000 Unemployment	***	***	***	***	***	1.02	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.08

Appendix A (Continued)

Table A.14 Results of Multilevel Model For Black Non-Hispanic Mothers Year 1990 Census Tracts Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	Poverty	Vehicle Ownership	Educational Attainment	Per Capita Income	Unemployment	Linguistic Isolation
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.09	2.05	2.05	2.05	2.05	2.05	2.05
Not Married	1.23	1.22	1.21	1.21	1.21	1.21	1.22
Female	1.21	1.20	1.20	1.20	1.20	1.20	1.20
Younger than 18 yrs	1.13	1.10	1.10	1.10	1.10	1.10	1.10
Older than 34 yrs	1.28	1.26	1.26	1.26	1.26	1.26	1.26
Primiparous	1.41	1.40	1.40	1.40	1.40	1.40	1.39
Low Gain	1.93	1.94	1.94	1.94	1.94	1.94	1.94
Excess Gain	0.80	0.82	0.82	0.82	0.82	0.82	0.82
Group Variable							
1990 Deprivation Index	1.01	***	***	***	***	***	***
1990 Poverty	***	1.00	***	***	***	***	***
1990 No Vehicle	***	***	1.03	***	***	***	***
1990 Low Educational Attainment	***	***	***	1.03	***	***	***
1990 Per Capita Income	***	***	***	***	1.03	***	***
1990 Unemployment	***	***	***	***	***	1.02	***
1990 Linguistic Isolation	***	***	***	***	***	***	1.03

Appendix A (Continued)

Table A.15 Results of Multilevel Model For Hispanic Mothers Year 2000 Census Tracts Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.12	2.11	2.11	2.12	2.12	2.11	2.11
Not Married	1.26	1.26	1.26	1.26	1.26	1.27	1.26
Female	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Younger than 18 yrs	1.26	1.26	1.26	1.26	1.26	1.26	1.26
Older than 34 yrs	1.39	1.39	1.39	1.39	1.39	1.39	1.39
Primiparous	1.62	1.62	1.62	1.62	1.62	1.61	1.62
Low Gain	1.37	1.37	1.37	1.37	1.37	1.38	1.37
Excess Gain	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Group Variable							
2000 Deprivation Index	1.08	***	***	***	***	***	***
2000 Poverty	***	1.06	***	***	***	***	***
2000 No Vehicle	***	***	1.08	***	***	***	***
2000 Low Educational Attainment	***	***	***	1.04	***	***	***
2000 Per Capita Income	***	***	***	***	1.07	***	***
2000 Unemployment	***	***	***	***	***	1.18	***
2000 Linguistic Isolation	***	***	***	***	***	***	1.07

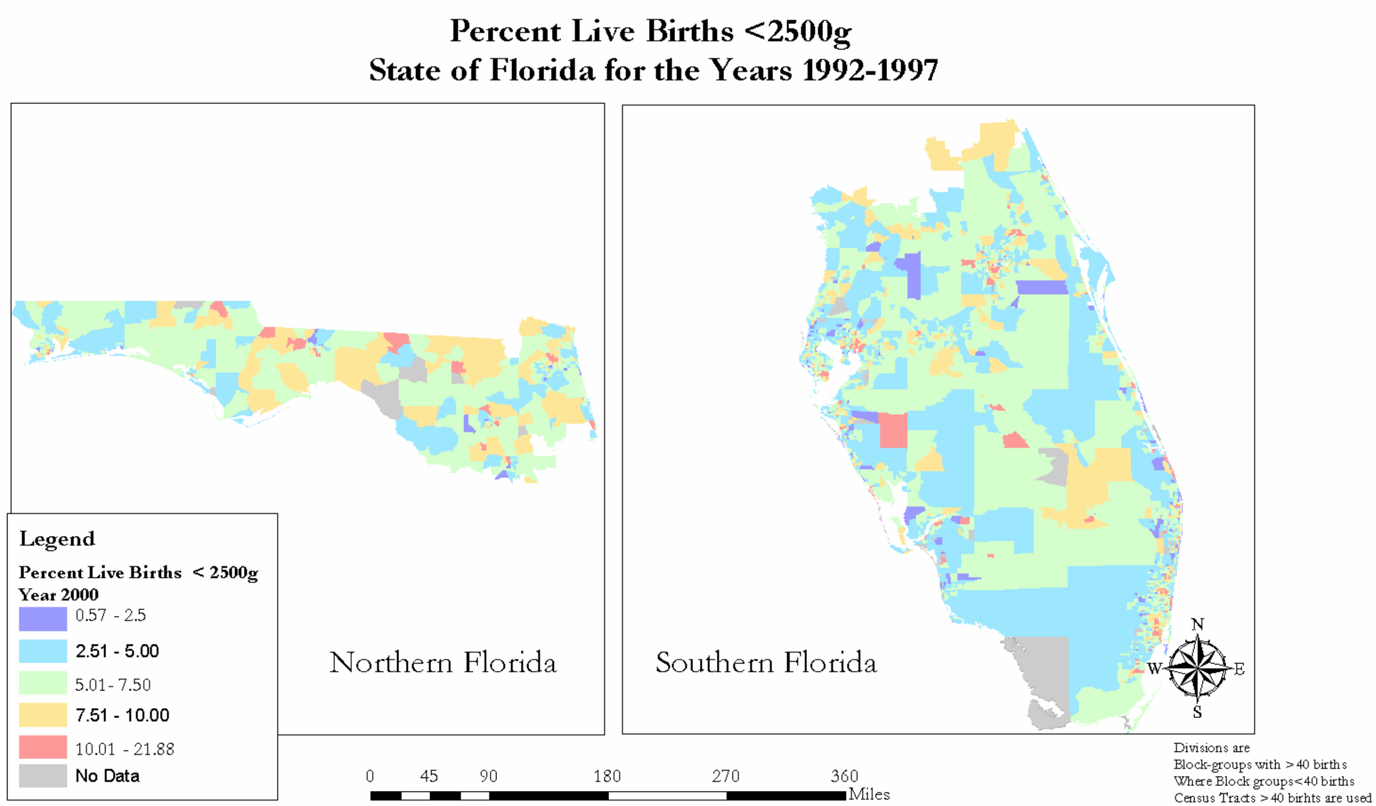
Appendix A (Continued)

Table A.16 Results of Multilevel Model For Hispanic Mothers Year 1990 Census Tracts Showing Odds Ratios For Individual and Group Level Variables.

	Full Model Deprivation Index	**Poverty**	**Vehicle Ownership**	**Educational Attainment**	**Per Capita Income**	**Unemployment**	**Linguistic Isolation**
Variables	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***	***Odds Ratio***
Smoking	2.11	2.12	2.11	2.12	2.12	2.12	2.11
Not Married	1.26	1.26	1.26	1.26	1.26	1.25	1.25
Hispanic	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Younger than 18 yrs	1.26	1.26	1.26	1.26	1.26	1.26	1.26
Older than 34 yrs	1.39	1.39	1.38	1.39	1.39	1.39	1.38
Primiparous	1.62	1.62	1.61	1.62	1.62	1.62	1.62
Low Gain	1.37	1.37	1.37	1.37	1.37	1.37	1.37
Excess Gain	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Group Variable							
1990 Deprivation Index	1.04	***	***	***	***	***	***
1990 Poverty	***	1.03	***	***	***	***	***
1990 No Vehicle	***	***	1.05	***	***	***	***
1990 Low Educational Attainment	***	***	***	1.02	***	***	***
1990 Per Capita Income	***	***	***	***	1.03	***	***
1990 Unemployment	***	***	***	***	***	1.05	***
1990 Linguistic Isolation	***	***	***	***	***	***	1.05

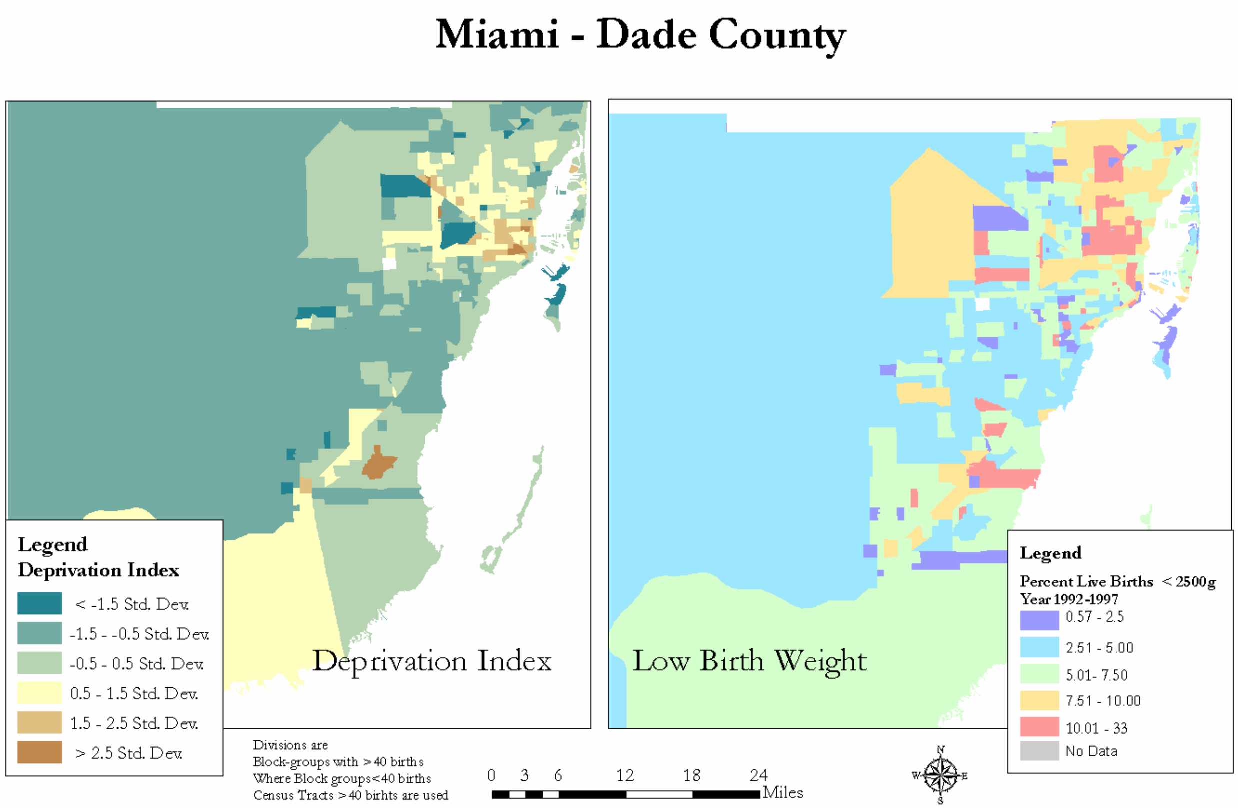
Appendix B: Low Birth Weight and Deprivation Maps

Map B.1 – Percent Live Births <2500g; State of Florida for Years 1992-1997



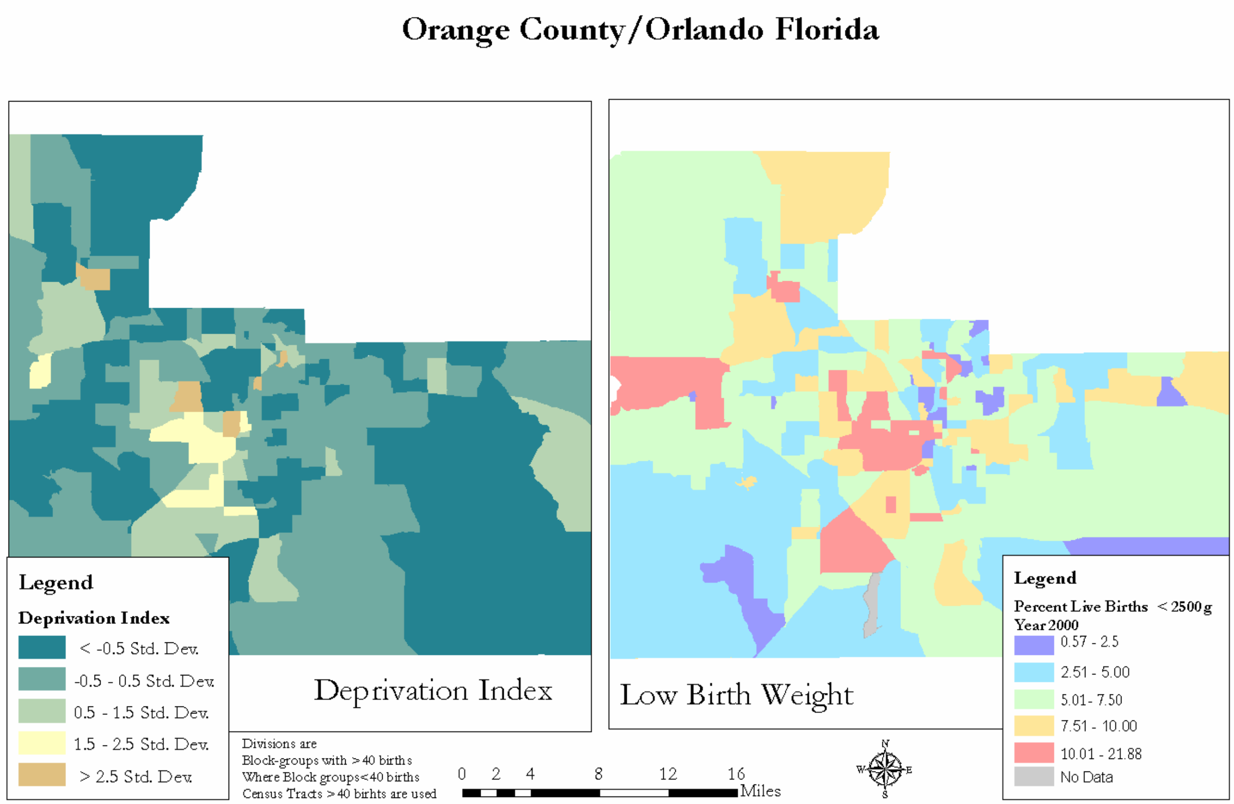
Appendix B (Continued)

Map B.2 – Miami, Dade County; Deprivation Index and Low Birth Weight



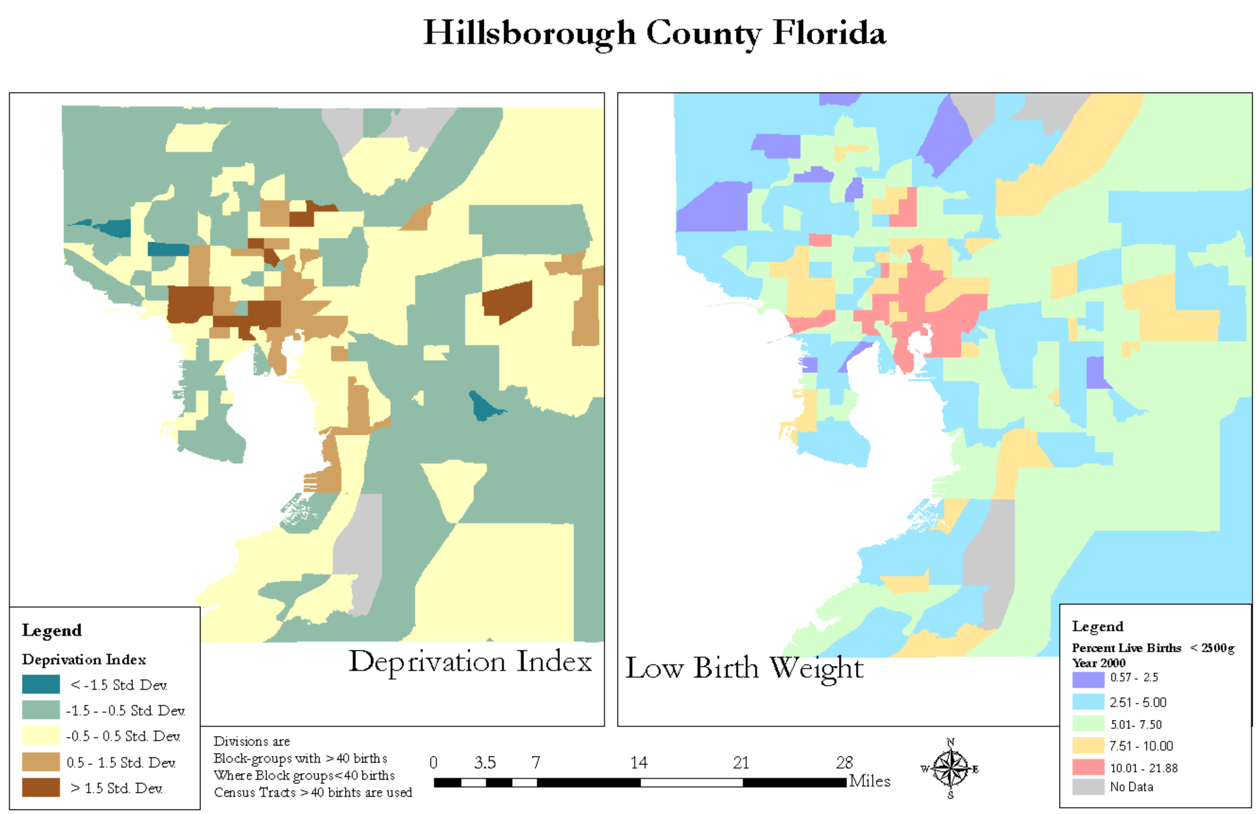
Appendix B (Continued)

Map B.3 – Orange County / Orlando Florida; Deprivation Index and Low Birth Weight



Appendix B (Continued)

Map B.4 Hillsborough County; Deprivation Index and Low Birth Weight



Appendix B (Continued)

Map B.5 – Jacksonville Florida; Deprivation Index and Low Birth Weight