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# INEQUALITY AND INFANT HEALTH: A MULTILEVEL APPROACH TO DISENTANGLING CORRELATES OF METROPOLITAN/NONMETROPOLITAN DISPARITIES IN LOW BIRTH WEIGHT INFANTS

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Patrice Johnelle Smith



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The thesis of Patrice Johnelle Smith was reviewed and approved* by the following:

Diane K. McLaughlin
Associate Professor of Rural Sociology and Demography
Thesis Adviser
Chair of Committee

C. Shannon Stokes
Professor of Rural Sociology and Demography

Leif Jensen
Professor of Rural Sociology and Demography
Director, Population Research Institute

Kathryn Brasier
Assistant Professor of Rural Sociology

Jonna M. Kulikowich
Associate Professor of Education

Stephen M. Smith
Professor of Agricultural and Regional Economics
Head of the Department of Agricultural Economics and Rural Sociology

*Signatures are on file in the Graduate School

**ABSTRACT**

To date, research has not adequately addressed geographic variation in birth weight due to individual- and structural-level characteristics in the US. If the health care needs of infants and children in nonmetropolitan areas are to be understood, an analytic approach capturing how both individual- and contextual-level inequalities operate is needed. This research utilizes multiple levels of rurality as one component of structural-level characteristics, along with individual-level characteristics, to examine variation in birth weights. Specifically, theoretical and empirical evidence is given for associations between biological, social, and behavioral characteristics and birth weight at the individual level, and residential, socioeconomic, social capital, social environmental, and health services characteristics and birth weight at the structural-level. With variation in birth weights across groups and places in the United States, it is important to understand which children are at risk of poor health outcomes and to identify how local conditions contribute to these outcomes. The ECLS-B merged with county-level data is used to examine this problem.

Results from this research indicate that most of the variation in birth weight is attributable to individual-level characteristics, such as gestation, plurality status, and maternal smoking behavior during pregnancy. However structural-level characteristics help to explain some of the variation. Various measures of rurality indicate that rural residents tend to have higher birth weights. Other structural-level measures, such as the percentage of residents in the county that are black, the number of Olsen-Type establishments in the county, and the number of health care personnel all have associations with average birth weights and the mean likelihood of low birth weight.

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# Chapter 1

## Introduction

Major improvements have been made in the area of infant and child health in the past century in developed nations. Developments in medical technologies have allowed most infants to survive past their first year of life. Yet despite advances in medical technologies, health disparities still exist in the United States in the first year of life and later in the life course. An often cited indicator of the social and health condition of a population is the infant mortality rate. The latest reports from vital statistics in the United States indicate that the infant mortality rate was 7.0 infant deaths per 1,000 live births in 2002, which is higher than infant mortality rates for the few years prior to 2002 (Mathews, Menacker and MacDorman 2004). Infant mortality rates have also been shown to vary widely across counties, with infant mortality rates for contiguous counties in the US ranging from a low of 3 to a high of 19 over the 1989-1999 time period (Smith 2003).

The most prevalent and dominate risk factor for infant mortality and developmental disorders is low birth weight, making the study of birth weight extremely important in trying to reduce poor infant health outcomes not only in the first few months of life but also later in the life course (Thompson et al. 2005). Simply using vital statistics measures, such as the infant mortality rate, to capture the health of infants and children in the United States may mask other underlying health disparities of the youngest members of the population. Measures capturing the health status of surviving infants and children, such as birth weight, may be more useful in understanding the persistence of disparities in health. Much like variation in infant mortality rates across places in the United States, Thompson and colleagues (2005) have found that regional variation in the rates of low birth weight exist in the US. Rates of low birth weight were found to vary from 3.8 to 10.6 per 100 live births across regions in the United States. This variation lends support for more targeted interventions at the individual and aggregate level to help eliminate disparities in birth weight.

While studies indicate that variation in birth weight exists, complexities arise when trying to account for this variation in birth weights. Individual-level risk factors for birth weight, such as biological, social, and behavioral characteristics of mothers and infants, have been researched extensively. Results from this research have produced consistent relationships between individual-level characteristics and birth weight. For example, premature infants and twins weigh much less at birth than full-term and singleton infants (Almond, Clay and Lee 2002). Racial/ethnicity differences in birth weight have also been found to be consistent over time. Specifically, black infants have higher rates of low birth weight than white infants while Hispanics infants have similar rates of low birth weight to whites (Gorman 1999). Smoking behaviors while pregnant have also been shown to increase the likelihood of having a low birth weight infant (Shiono and Behrman 1995). However these models have only explained a small amount of the variability that exists overall in birth weight (Kramer 1991).

More recent research highlights the importance of the environment and communities in contributing to the risk of low birth weight (Collins and David 1990; Coulton and Pandey 1991; Gould and LeRoy 1988; Hummer 1993; O’Campo et al. 1997) and other infant health outcomes. Results from this research suggest that structural-level characteristics modify the effects of individual-level characteristics in determining birth weights. Others argue that structural-level characteristics have an independent effect on individual health outcomes (Soobader and LeClere 1999), yet this type of relationship has not been examined for infant health outcomes. The relationship between structural-level risk factors and infant health is not as well established as individual-level determinants and needs to be investigated for different population groups, such as by race/ethnicity and residence. Further these two levels of aggregation need to be merged in theoretical explanations of infant health outcomes in order to understand how individuals are at risk of having a low birth weight infant based not only on their own individual-level characteristics but also due to the characteristics of the geographic location in which they live.

To date, research has not addressed geographic differentials in birth weight due to individual- and structural-level characteristics based on a national sample of births in the United States. Results from international and local studies indicate that the risk of low birth weight falls unevenly across space and for the infant population (Basso et al. 1997; Crosse et al. 1997; Larson, Hart and Rosenblatt 1997; O'Campo et al. 1997; Unger et al. 1988). If the health care needs of infants and children in nonmetropolitan areas are to be understood in order to inform policy decisions about infant health, an analytic approach capturing how both individual- and structural-level inequalities operate is needed.

Prior research focusing on rural and urban differences in birth weight has mostly used dichotomous measures of residence, such as rural and urban or metropolitan and nonmetropolitan designations. Few population based studies of infant morbidity patterns have been conducted, and smaller clinical studies have not addressed rural and urban differences in outcomes. This research utilizes various operationalizations of rurality as one component of structural-level characteristics along with individual-level characteristics to examine birth weight. With variation in birth weights across groups and places in the United States, it is important to understand which children are at risk of lower birth weights and to identify how local conditions contribute to poor infant health outcomes.

Given the variation that exists in birth weight and a rise in infant mortality rates in the United States, it is important to address the factors that place individuals at the risk of having a low birth weight infant. It is also an important time to consider this topic, because two of the primary goals advocated in the Healthy People 2010 report include increasing the quality and years of healthy life for individuals and eliminating health disparities, with specific reference to disparities due to geographic location (U.S. Department of Health and Human Services 2000). This research seeks to address the issue of variation in birth weight based on individual- and structural-level characteristics and to offer insight into how negative health outcomes can be avoided for infants in all types of places in the United States.

## Objectives and Outline

The objective of this research is to detail risk factors associated with variation in birth weight. In order to accomplish this goal, two separate sets of analyses are conducted. First, individual-level characteristics of infants and their mothers based on a nationally representative sample of births from 2001 for the U.S. are examined as they relate to higher or lower birth weights and the odds of having a low birth weight infant. Biological, social and behavioral characteristics of individuals are considered. Additional analyses looking at race-, sex-, and plurality-specific models are also explored in order to better understand the variation in birth weight across infants. Second, structural-level traits associated with the places that these infants and mothers live are combined with individual-level characteristics in order to clarify how birth weights at the individual-level are influenced by factors at these two discrete levels.

This thesis is organized in the following manner. Chapter 2, entitled “The Context,” offers theoretical explanations for variation in birth weight at individual- and structural-levels. A model of geographic differentials in birth weight is developed that divides individual-level characteristics into biological, social, and behavioral factors and structural-level measures into socioeconomic, residential, social capital, social environment, and health services characteristics. A comprehensive examination of theoretical explanations for differences in birth weight at the individual level is provided based on these two distinct levels of analysis.

Chapter 3, entitled “Biology and Social Conditions: The Relationship between Individual-Level Characteristics and Birth Weight,” uses data from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) to investigate how individual-level characteristics influence birth weight and low birth weight status. More specifically, this chapter explores variation in birth weight and the likelihood of low birth weight status based on social, biological, and behavioral characteristics of mothers and infants. After full models are examined, race-, sex-, and plurality-specific models are explored to account for the differences that exist in birth weight and low birth weight status in the full models with all infants. Chapter 4, entitled "Rurality, Income Inequality, and Contextual Effects: Implications for Birth Weight Using Multilevel Methods," uses multilevel modeling techniques to explore the impact of structural-level measures on birth weight and the likelihood of low birth weight status of infants. Particular attention is given to the level of rurality for an infant's county of residence at the structural-level in order to tease out residential variation in birth weights for nonmetropolitan residents. Data for this analysis come from several secondary sources aggregated to the county level, including Economic Research Service Rural-Urban Continuum Codes; 2000 US Census of Population and Housing, Summary File 3 (SF3); 2000 County Business Patterns; 2000 Uniform Crime Reports; and the 2004 Area Resource Files. These data sources are merged to the ECLS-B using state and county federal information processing standards codes included in the ECLS-B. The incorporation of multiple levels in this analysis allows for a more comprehensive understanding of how the positioning of individuals in the places they live offers better explanations for differentials in birth weights for infants in the United States. Chapter 5 provides a summary of the conclusions and implications from this research. This chapter also explores some new issues that may be emerging in the study of birth weight and discusses future directions for this research.

# Chapter 2

# The Context

## Introduction

A complex set of individual- and structural-level characteristics influences individual birth weights. Birth weight has been shown to vary between individual infants, as well as among regions in the United States (Thompson et al. 2005). To date, research has not adequately addressed geographic differentials in birth weight due to differences in individual- and structural-level characteristics in the United States using an integrative theoretical framework to connect these two levels of risk. Most research on the topic of low birth weight or infant mortality has been confined to individual-level studies focusing on the socioeconomic status and behavioral characteristics of families or descriptive analyses of income inequality and aggregate level infant health outcomes.

If the health care needs of infants and children in the U.S. are to be understood, an analytic approach capturing how both individual- and local structural-level inequalities operate simultaneously to influence individual infant health outcomes is needed. A rural advantage, meaning lower rates, in infant mortality has been observed for some regions and some populations in the United States (Morton 2005). Less attention has been given to birth weight differentials for rural and urban residents. Prior research focusing on rural and urban differences in infant health outcomes has mostly used dichotomous measures of residence, such as rural/urban or metropolitan/nonmetropolitan, which offers little insight into what that residential category means for differences in infant health.

Few population based studies of infant morbidity patterns across residential areas have been conducted, and smaller clinical studies have not addressed rural and urban differences in outcomes.

Given the variation in rates of birth weight across groups and places in the United States (Larson, Hart and Rosenblatt 1997), it is important to understand which children are at risk of poor health outcomes and to identify how the structure of places in which infants and their families live impacts their health independently of individual biological, social, and behavioral characteristics. Theoretical explanations capturing the multidimensionality of inequality across places must be articulated in order to obtain a more comprehensive understanding of how the places in which individuals live and interact with one another influence individual health outcomes (Levine 1995; Soobader and LeClere 1999). The incorporation of a multidimensional theoretical framework may also help to determine why birth weights continue to vary across places in the United States.

This chapter offers theoretical explanations and empirical evidence for the links between infant health and individual- and structural-level characteristics. Relationships between structural-level characteristics and individual infant health outcomes are detailed along with discussions about individual-level characteristics of infants and their families that are important in determining birth weight. The discussion of structural-level characteristics focuses on the importance of the distribution of inequality across space and how the geographic nature of inequality may lead to variation in outcomes (Soobader and LeClere 1999; Wilkinson 1996). An argument is also made for the inclusion of a more refined measure of rurality to be incorporated as one structural component in this research.

## Theoretical Framework – Inequality and Stratification in Health

When studying health and inequality, it is necessary to understand how the local context affects individual health outcomes. However, the structures and infrastructures influencing individual birth weights are not equally distributed across places in the U.S. Specifically, birth weights of individual infants are most likely to be influenced by the availability and access to social services and medical care devoted to prenatal care, nutrition, and early infant and childhood health. Different places throughout the United States offer environments that influence the availability of these types of resources and infrastructures that promote a healthy pregnancy and birth (Gorman 1999). Further, the characteristics of place can assist in directing behavior through attitudes and values created by the various alternatives and costs associated with a given behavior (Massey, Gross and Eggers 1991). Structural level characteristics such as residential, socioeconomic, social capital, social environmental, and health service features contribute to the unequal distribution of health outcomes across places. This chapter explores the theoretical and empirical relationships between these characteristics and birth weight as well as the distribution of birth weight across places based on these characteristics. One of the most researched relationships used to examine this distribution is between income inequality and health outcomes.

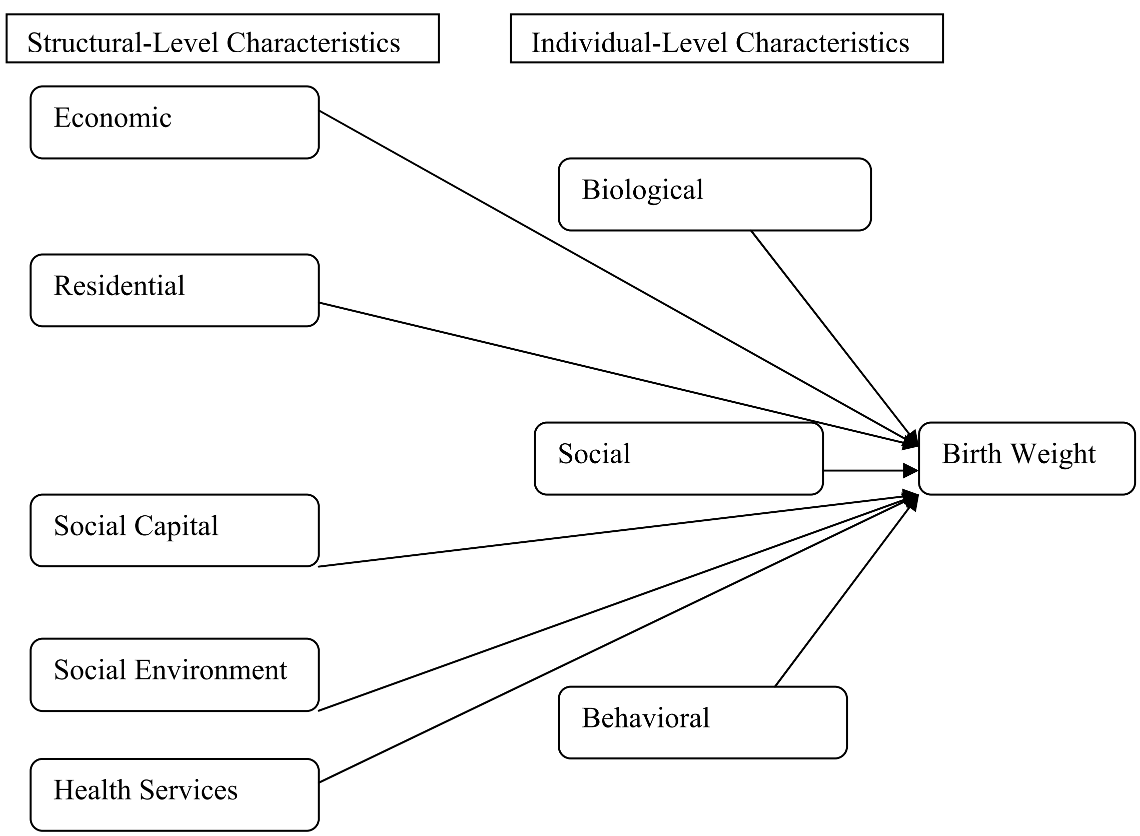
Inequality is used as an aggregate measure to capture the distribution of resources within a place as well as the variation in resources across places (Daly et al. 1998; Lobao 1990; McLaughlin et al. 2006). Many studies have documented a strong positive relationship between income inequality and aggregate levels of adult mortality (Kaplan et al. 1996; Kawachi and Kennedy 1997; Kennedy, Kawachi and Prothrow-Stith 1996; McLaughlin and Stokes 2002). Similar patterns between inequality at the structural level and infant health outcomes are likely to hold. When aggregate measures of income inequality are incorporated into studies of individual adult mortality risk, a positive relationship is found after adjustments for age, sex, and mean income of the community of residence (Fiscella and Franks 1997). Still individual measures of income, rather than income inequality at the structural level, explain more of the variance in individual health outcomes in this study. This is largely attributable to the effect of individual socioeconomic status as a key predictor of mortality at the individual level. Further research on this relationship needs to be explored for infant morbidity and mortality patterns to ascertain if the socioeconomic characteristics of families are transferred to infants.

These results indicate that the unit of analysis and the level of aggregation are both important to understanding the relationship between inequality and individual health outcomes (Soobader and LeClere 1999). However Wilkinson (1997a, b) contends that results from studies examining this relationship do not nullify the structural inequality and individual health relationship. Instead, Wilkinson argues that income inequality may be completely identified through measures of individual socioeconomic status at lower levels of aggregation, such as neighborhoods. This argument supports the longstanding relationship in studies of population health between individual socioeconomic status and mortality and morbidity differentials. Still others argue that inequality affects the nature of these relationships with reference to a spatial context that is independent of individual characteristics, specifically socioeconomic status (Kaplan et al. 1996; Kawachi et al. 1997; Lynch and Kaplan 1997; Smith 1996; Wilkinson 1996). The central hypothesis of my research states that income inequality and other structural-level measures will have an effect on birth weight independent of individual level biological, social, and behavioral characteristics.

In order to explain the origin of this central hypothesis, two theoretical and empirical literatures must be explored and combined into a multidimensional theory of inequality and infant health outcomes, with specific reference to birth weight. First, sociological and public health research is examined at the structural-level to see how aggregate level inequality and other structural-level characteristics influence individual infant health outcomes. Second, an exploration of the individual-level risk factors often researched in the pediatric literature focusing largely on biological and behavioral mechanisms of families are explored, as well as social conditions of infants and their families detailed in epidemiological studies on individual health risks. Difficulty emerges when connecting these two distinct levels of risk in order to capture the structure of places and how structural-level characteristics and the geographic distribution of inequality would influence the health of individual infants in specific geographical locations.

A model of geographic differentials in birth weight, presented in Figure 2.1, is developed in order to separate these two levels of risks. Specifically this model synthesizes socioeconomic, residential, social capital, social environment, and health service characteristics at the structural-level, while biological, social, and behavioral characteristics of infants and mothers are included at the individual-level. Each level is seen as unique and independent in contributing to the health status of individual infants. The incorporation of structural-level characteristics is necessary, because contextual-level characteristics are presumed to have an added influence on individual birth weights that is apart from the effects of individual-level characteristics (Blalock 1984; Duncan, Jones and Moon 1998; Jones and Duncan 1995). A detailed discussion of the theoretical explanations for these characteristics for individuals and the local context which involves two distinct levels of aggregation is given below.

Figure 2.1: Model of Geographic Differentials in Birth Weight



**Structural-Level Characteristics and Infant Health Outcomes**

As mentioned above, previous research has found a relationship between infant health and contextual-level characteristics (Brooks 1980; Gorman 1999; LaVeist 1989; Lillie-Burton and LaVeist 1996). Structural-level measures used in these studies include such things as the availability of educational opportunities, access to and availability of prenatal care, median household income, unemployment rates, proportion of families headed by a female, racial and socioeconomic residential segregation, and the number of physicians for the population. Yet many studies of birth weight have not focused on the importance of inequality at the structural-level and its association with individual risks for having a low birth weight infant. In discussing structural level characteristics, it is important to situate individuals, both infants and parents, within the geographic location in which they live, work, and interact with other people. From this perspective, an individual's health is influenced by their own individual characteristics or the transferal of characteristics from parent to infant, but it is also shaped by whether the individual is surrounded by generally better-off or worse-off neighbors. Further, a focus on the proximity of individuals to poor social and economic conditions and access to health-promoting services also must be considered (Gatrell and Rigby 2004).

Another important consideration to be given to the study of health from a structural perspective is the underlying idea that social groups are legitimate units of analysis, and structural-level factors may influence individual outcomes independently of individual characteristics or modify how these individual-level characteristics are related to infant health outcomes (Diez-Roux 1998). Theoretical explanations for structural-level characteristics as they relate to individual birth weight are detailed below, first by describing a geographic framework of inequality and then discussing the structural level characteristics presented above in Figure 2.1.

## The Geographic Nature of Inequality

The association between income inequality and mortality has been researched extensively including cross-country comparisons (McIsaac and Wilkinson 1997; Wilkinson 1992), national studies (Kaplan et al. 1996; Kennedy, Kawachi and Prothrow-Stith 1996), and state level analyses in the United States (Kaplan et al. 1996; Kawachi and Kennedy 1997; Kennedy, Kawachi and Prothrow-Stith 1996). However, Soobader and LeClere (1999) argue that many of the current frameworks for examining this relationship disregard the geographic nature of inequality and how inequality is distributed among different levels of aggregation. By doing so the pathways by which inequality may influence health and individual risk may be overlooked. These authors further argue that income inequality shapes the "physical and social landscape of individuals" (1999: 734) while also influencing their economic and social standing within that geographic space. More recent studies examining county level comparisons in mortality in the US find an association between income inequality and mortality (McLaughlin and Stokes 2002; McLaughlin, Stokes and Nonoyama 2001), which lend support to the above claim. One key set of characteristics at the structural-level to emerge as important to influencing individual health outcomes is economic characteristics of places. These characteristics involve various conceptualizations of economic structures in places.

## Socioeconomic Characteristics

*Income Inequality*

Research has found a strong positive relationship between income inequality and mortality and morbidity patterns. The relative-income hypothesis combines individual- and structural-level measures to look at various health outcomes. This hypothesis states that over and above individual income, a society's income distribution impacts an individual's health (Wilkinson 1997c). Wilkinson (1996a, b) argues that highly unequal income distributions in geographic areas are indicative of poverty among affluence, and this spatial distribution of income adds a new dimension to the income inequality and health relationship. It is further argued that the spatial location of inequality in society can lead to negative individual health outcomes (Daniels, Kennedy and Kawachi 1999). The relative-income hypothesis also states that an individual's health status depends on their rank within the income distribution based on their individual level of income and/or the distance between their income and the average income for a certain group of individuals (Kawachi, Subramanian and Almeida-Filho 2002).

Recent articles by Lynch and colleagues (2004a, b) indicate that support for the idea that income inequality is a primary determinant of population health in developed nations is not as strong as was once suspected. However, one problem with their review of the literature has to do with the level of aggregation (such as states) at which analyses are being conducted, as well as with data restrictions and various measures of income inequality being used. At the individual level, the absolute-income hypothesis states that higher individual income is associated with better health outcomes. Yet this hypothesis does not reflect the complexity of the relationship between income inequality and health, which is articulated in the relative-income hypothesis, because it does not consider the impact of larger contextual factors and the relative positioning of individuals within a spatial context on this relationship and how an individual's relative position then increases their individual risk of having a low birth weight infant (Subramanian, Kawachi and Kennedy 2001).

Two main propositions are often mentioned as explanations for the relative-income hypothesis in relation to health outcomes. First, the inequitable distribution of income for a given population may be associated with a set of economic, social, political, and institutional processes that represent a systematic underinvestment in various forms of infrastructure (social, human, physical, and health). This dimension of the relative-income hypothesis has also been associated with the theoretical construct of the triple health jeopardy (Blau 1977; Massey, Gross and Eggers 1991). The systematic underinvestment in infrastructure could impose a material dimension on the inequality-health link for the poor and working class individuals in the United States. Specifically, education about proper prenatal care may not be available for low income individuals in high inequality areas. Likewise, proper maternal and infant health facilities may be missing if the local infrastructure and population do not support this type of specialized care. This isolation may result in poor access to a set of infrastructures that would allow individuals to seek medical care, quality education and employment, and affordable, safe housing. Further, these characteristics based on the opportunity structures of place can be passed from parents to their infants.

Second, individual perceptions of one's position in the social environment may be based on society's inequitable income distribution, which may in turn impact the individual's health (Daly et al. 1998). This second proposition supports the psychosocial interpretation of the relative income hypothesis, which argues that people internalize their position in the inequality structure and this internalization process influences individual health outcomes (Marmot and Wilkinson 2001; Wilkinson 1999a, 1999b). Stress related to an individual's socioeconomic positioning in a given area, such as wondering about how to maintain an income if maternity leave is not an option associated with one's job, could lead to poor health outcomes for individual infants if the mother has no other options for economic and medical support. Overall the relative-income hypothesis would argue that higher levels of income inequality would increase individual risks of having a low birth weight infant, because places with highly unequal income distributions would be less likely to invest in social, political, medical, economic, and educational programs for its population.

*Consequences of Income Inequality*

Beyond the propositions made in the relative-income hypothesis, research has indicated that the social and physical features of the places people live make an independent contribution to health outcomes rather than just acting as a proxy for individual level data (McIntyre and Maciver 1993; Susser and Susser 1996a, b). Variables at the aggregate level measure a different concept than corresponding measures at the individual level (Geronimus, Bound and Neidert 1996; Schwartz 1994). For example, measures of income at the individual level are not the same as median household income or income inequality at the structural level. While individual measures of income, education, or occupational status may affect individual health outcomes, the social, economic, and cultural characteristics of places may also influence the relationship between these structural-level characteristics and individual measures of health (Susser and Susser 1996b).

It is important to understand how the inequality structure of places is likely to have direct consequences on individual health by shaping the social and economic structure of places (Soobader and LeClere 1999). Jargowsky (1996) contends that income inequality reveals itself in a geographic context through urbanization and decentralization leading to residential economic segregation. Therefore rich and poor households are spatially separated or segregated. While the nature of this spatial relationship may hold for metropolitan residents, the isolated living conditions in nonmetropolitan areas may foster a similar type of residential economic segregation.

The idea of residential economic segregation is important to health because the segregation of individuals within places is likely to influence the group's investment into social services and public goods within an area. Three types of scenarios regarding the distribution of social services and public goods based on the level of income inequality in a geographic location could be observed. First, places with low levels of income inequality have more equitable sharing of resources which allows members of the disadvantaged groups to benefit from the resources of the more advantaged groups. With moderate levels of income inequality, sharing of resources is reduced and the physical separation of the rich from the poor becomes more visible. Finally, at extreme levels of income inequality, what Massey (1996) has referred to as the "hour-glass" distribution", the rich segregate themselves socially, economically, and politically from the poor and physical space and services are no longer shared among these groups.

For both nonmetro and metro residents, high levels of income inequality could lead to fewer services being available in the local area (Lowe 1994; Simpson et al. 1994; Wilkinson 1997c, 1999a). Rich nonmetro residents could travel to more populated areas to receive services and goods, while poor nonmetro residents may be at a further disadvantage if social services and public goods are not available to them locally and they are unable to access these resources outside of their local geographic area due to high costs associated with traveling to other areas.

Overall the segregation of groups based on high levels of income inequality leads to less investment in that geographic location in social, economic, and political resources such as health services, education, and employment which helps to make the link between income inequality and higher risks of poor individual health outcomes (Soobader and LeClere 1999). More simply stated, differential access to social services and public goods can be attributed to the stratification of individuals into resource rich and poor places which in turn lead to differential health outcomes. And while most studies have found a relationship between income equality and adult health outcomes, this research posits that similar patterns should be observed for infant health outcomes and, specifically, birth weight. Based on the framework of the geographic nature of inequality presented above it is hypothesized that income inequality at the county level will have a positive, independent effect on individual birth weight even with the inclusion of socioeconomic measures of individual families in the models. However, because high income inequality is believed to foster underinvestment in infrastructure and services, other structural level measures are also likely to impact individual birth weights, and may reduce the direct effect of income inequality on birth weight.

*Other Socioeconomic Characteristics*

Beyond measures of income inequality, other socioeconomic resources at the structural-level, such as median household income, education levels, and unemployment rates, are direct measures of the resources available to individuals in a particular geographic area and are hypothesized to have an independent relationship with individual birth weight. These types of measures indicate the area's ability to provide services and resources to women prior to and during pregnancy and to their infants after birth (Gorman 1999). In addition, if economic circumstances of a particular area prevent women from seeking out prenatal care or health services due to expenses or access restrictions, then the risk of having a low birth weight infant is likely to increase. Further, if a pregnant woman lives in an economically depressed area with high unemployment rates she may have a different outlook about her own health and have that perception translate into poor outcomes for the health of her infant. Pregnant women that have not had the opportunity to fulfill their own personal goals may not see how taking care of their infant while pregnant will lead to better opportunities for their child (Gorman 1999). Therefore, poor socioeconomic conditions in an area can lead to underinvestment in individual health, affecting birth weight.

## Residential Characteristics

*Rurality*

Little work to date has considered the diversity of rural areas, or incorporated such measures into an analysis looking at the impact of multiple nonmetropolitan residential designations on variation in birth weights. Morton (2004) has shown that different mortality rates exist for varying levels of rurality when analyzing age-adjusted and cause-specific adult mortality. These differences are not observed when just comparing metropolitan and nonmetropolitan counties. If differences between metropolitan and nonmetropolitan infant health outcomes are to be understood, the complexity of the concept of rurality must be considered. The assumption that all rural areas are homogenous is misleading, and research on rural/urban differences should consider the diversity that exists across rural places and people (Morton 2004). Key aspects of rurality include access to services, geographic and social isolation, and low population density.

The concept of adjacency contributes to understanding differences in rural health outcomes, because this concept provides insight into underlying economic and social characteristics of counties (Morton 2004). Specifically adjacency in a spatial context represents the commuting patterns for employment, income distributions, and the transfer of goods and services across space. Adjacency is also important when looking at utilization and access to such goods as health care, food, education, and other social services. However, without knowing the types of services available in adjacent areas, little is known about what this concept means for accessing goods and services.

Yet, the health conditions of infants in rural areas are shaped by a different set of social and economic conditions that influences such things as educational systems, employment opportunities, transportations systems, and civic structures that are very different than those in metropolitan areas (Morton 2003). With smaller population sizes and less densely populated areas, residents of nonmetro areas often do not deal with the same type of market forces that drive employment, education, and health care services in metro areas. Health services may not be financially viable with an isolated and low density population (Simpson et al. 1994) This may lead to less effective and efficient systems for providing access to social services and public goods for nonmetro residents which in turn results in differential infant health outcomes for nonmetro residents.

Also important to consider in discussions about metropolitan/nonmetropolitan differences in health outcomes are issues dealing with health care service utilization and access to services (Farmer, Miller and Voth 1984; Frankenberg and Thomas 2001; Heaphy and Bernard 2000). Rural residents are often reported to have poorer health outcomes than urban residents due to poor access to material resources, including medical care resources (Clarke, Farmer and Miller 1994; Straub and Walzer 1992). Pregnant women in rural areas are also less likely to receive adequate prenatal care (Hughes and Rosenbaum 1989). This may be due to less availability of this type of medical service in nonmetro areas or prohibitive factors, such as the distance to and costs associated with prenatal care, due to location and access of these types of services.

Residents of rural areas may be at a disadvantage over and above more traditional measures of income inequality (Hayward, Pienta and McLaughlin 1997) if they do not have access to or the ability to seek out maternal or infant health services, such as prenatal care or specialized health care needed at the time of delivery. This may be due to specific prenatal and early childhood health services not being available for a small and isolated population, as well as the difficulty associated with traveling a long distance to receive medical attention if the family has a low income and cannot afford transportation costs or medical insurance. Yet, despite these structural barriers to better health outcomes, research indicates that infant mortality rates are not higher due to isolation of rural residents or health service availability (Farmer, Clarke and Miller 1993; Office of Technology Assessment 1990). Similar results may be likely for low birth weight in rural areas.

*Minority Concentration*

Researchers are beginning to investigate the way in which the concentration of minorities exerts an influence on health over and above measures of socioeconomic status and race/ethnicity at the individual level (Ellen, Mijanovich and Dillman 2001; Evans and Kantrowitz 2002; Geronimus, Bound and Waidmann 1999). Work by LaVeist (1989) reports that poorer health outcomes are observed for more segregated communities with higher concentrations of minorities. Social and political power may be lacking in areas with higher concentrations of minorities (LaVeist 1989; Zekeri 1997).

Characteristics of places can shape behaviors and attitudes about health. The availability of health and social resources based on these behaviors and attitudes can impact health outcomes. If political power is lacking in areas with a high concentration of minorities, the need for services for this population may be overlooked or ignored by the politically elite population. Therefore some racial and ethnic minorities may live in areas that have poor social and economic characteristics that are likely to increase their risk of having a low birth weight infant (Gorman 1999), since they have little voice in developing social and health infrastructures for their place of residence. Another explanation that could be applied to health outcomes at the individual-level and minority concentration has to do with the underinvestment of capital resources in areas with high minority concentrations compared to predominately white areas (Colclough 1990). This underinvestment then translates into low wages, fewer quality employment opportunities, less health services, and a poorer housing infrastructure (Zekeri 1997). If women in these areas, minorities and non-minorities alike, do not have resources to invest in their own health or the health of their infants and have very little access to or availability of services, individual birth weights are likely to be lower in areas with a high minority concentration.

## Social Capital Characteristics

In recent years, public health research has begun to examine the relationship between social capital and health (Kawachi, Kennedy and Glass 1999; Lochner, Kawachi and Kennedy 1999; Lomas 1998; Rose 2000; Veenstra 2000). Debates over the proper operationalization of social capital remain alive in this literature. A recent article by Carpiano (2006) argues that social capital is an important structural-level characteristic influencing health by affecting social support, social leverage, informal social control, and community organization participation. By being actively involved in social activities in one's community, individuals may feel a sense of obligation to look after the health and well-being of others in the community. Further, the structures associated with social organizations can either encourage or discourage a shared sense of encouragement, a sense of belonging, and improved social relationships (Lomas 1998). Positive attachments to a social group could lead individual women to take better care of themselves while pregnant, resulting in better infant health outcomes.

Having access to a variety of people in these formal or informal organizations can lead to more knowledge about prenatal care, nutrition, and behavioral practices for pregnant women. Certain types of organizations that people belong to, such as religious organizations, are likely to have norms about acceptable behaviors for pregnant women. Having a system of informal social control could therefore translate into lower individual risks of having low birth weight infants. Belonging to a social group may also provide emotional and financial support for individual pregnant women who may otherwise not have a support system of any kind, leading to better individual infant health outcomes.

**Social Environment Characteristics**

High crime rates at the structural-level are likely to impact behavioral characteristics at the individual-level. Living in fear or being exposed to crime in your living environment (Sampson, Raudenbush and Earls 1997) can influence women's behavior while pregnant. Pregnant women living in areas with high crime rates may experience higher levels of stress and turn to poor behavioral characteristics, such as smoking or consuming alcohol, to cope with the fear of living in a high crime area. These behavioral characteristics are known to increase the risk of having a low birth weight infant. Poor access to resources, such as steady employment, social support, and health services, particularly prenatal care, due to a weak social environment can have negative impacts on infant health as well (Macintyre, Maciver and Sooman 1993; Wakefield et al. 2001). Further living in fear of crime can be detrimental for the health of infants. For example, if women living in areas with high crime rates are fearful of leaving their homes, they are less likely to exercise, take part in community events/activities, or to seek health care.

**Health Services Characteristics**

Having a large number of specialized medical personnel or hospitals in an area may affect the access that pregnant women have to health care services. However if the availability and cost of medical services, including prenatal care, are too great, pregnant women may not have the incentive to seek medical care (Gorman 1999). Costs can include more than the direct monetary costs of services, and can include such things as distance to services and income lost due to time away from work. If individual women do not see preventative health care as an important part of pregnancy, then these women increase their risk of having a low birth weight infant by not seeking out early prenatal care. It should also be noted that just having a large number of physicians or hospitals in an area does not translate into better health. Certain women may move closer to an area with specialized health care in order to treat health complications during the pregnancy. However, this treatment may not ensure an infant will be born of normal weight. It should also be noted that pregnant women may live in an area with a high concentration of medical specialists or facilities but may not have the economic resources to access specialized medical care. Having a concentration of medical services and specialists available may not translate into better health outcomes for individual infants.

Rural residents may face different barriers to receiving medical care while pregnant than residents of metropolitan counties. Since medical care in the United States is driven by competitive market assumptions, the focus on the individual rather than the population may work against rural pregnant women (Morton 2003). While insurance coverage rates are similar for rural and urban populations, rural residents are much more likely to be underinsured which could mean no or little insurance coverage for prenatal care and maternity-related care (Comer and Mueller 1992). Further the specialized medical care for pregnant women and infants is likely to be overshadowed by the need for medical care for the elderly in rural areas (Morton 2003). Even if care is available, quality of care, especially for problem pregnancies, may be low due to limited experience of medical personnel with rare complications. If geographic areas are unable to provide the medical services needed for pregnant women and infants, the risk of low birth weight in these areas may increase.

Each of the structural level characteristics mentioned above is hypothesized to have an independent effect on individual birth weight. However without the inclusion of individual level characteristic of infants and their families within this framework of multidimensional inequality, the effects of structural level measures are likely to be overestimated. The next section of this chapter offers theoretical and empirical explanations for the associations between birth weight and the biological, social, and behavioral characteristics of infants and their families.

## Individual-Level Characteristics and Infant Health Outcomes

At the individual level, three distinct sets of characteristics emerge as important in determining birth weight. These include biological, social, and behavioral characteristics. Each of these groupings of characteristics poses a different level of risk for infant health, particularly birth weight. Biological characteristics of the mother and infant are the most endogenous of the individual-level characteristics. Traditionally, biological measures have tended to account for most of the variation in birth weight. Without taking account of biological measures, effects of other individual- and contextual-level measures will be biased.  However, social and behavioral characteristics can affect many of the biological processes and their relationships with birth weight.  These characteristics are explored below.

## Biological Characteristics

### *Sex*

Sex is one of the key biological characteristics included in studies on birth weight and infant mortality.  Most often a variable of the child's sex is included in infant health research with little explanation given as to why birth weights are likely to differ for male and female infants, and this measure often serves as a control variable.  Studies have documented that when infants of the same gestational age and birth weights are compared, male infants have greater mortality rates than female infants (Lemons et al. 2001; Stevenson et al. 1998).  However results from these studies do not indicate if male or female infants are more likely to be born with higher birth weights or a greater probability of low birth weight status.

### *Gestational Age*

More concrete evidence is found for the relationship between gestational age and birth weight.  The gestational age of the infant is an important biological characteristic of the infant, because premature infants are much more likely to be born low birth weight (Allen, Donohue and Dusman 1993; Hack and Fanaroff 1999; Hack, Friedman and Fanaroff 1996; Petrou 2005).  Premature infants are those born before 38 weeks of gestation.  Infants that are born extremely premature run the risk of being born with very low birth weights (less than 1,500 grams).  One concern with the relationship between prematurity and birth weight is the economic cost of preterm birth. Infants that are preterm and low birth weight that survive compared to those that die have much higher neonatal costs (Petrou and Davidson 2000; Petrou 2003). Low birth weight preterm infants are also much more likely to need hospital and community health services (Brooten et al. 1986; McCormick et al. 1991). Overall low birth weight premature infants have higher risks of infant mortality and other infant and childhood morbidity patterns (Vohr et al. 2000).

*Plurality Status*

Increases in the rate of multiple births in the past two decades have led to an increasing incidence of low birth weight, because multiple births are at a higher risk of resulting in low birth weight compared to singleton births (Blondel et al. 2002; Cohen et al. 1999; Martin and Park 1999; Ricketts, Murray and Schwalberg 2005). Results of twin studies conducted between 1985 and 1995 indicate that the average twin only weighs 2,400 grams, making a twin infant low birth weight. However, when comparing twins with the same mother, the heavier twin tends to weigh 300 grams more than the lighter twin, on average (Almond, Clay and Lee 2002). Results from this study also find that the heavier twin within twin-pairs is no more likely to survive the first year of life compared to the lighter twin. Therefore, infants from multiple births are at a higher risk of being lower birth weight compared to singleton birth infants.

*Maternal and Infant Health Complications*

Two other key biological characteristics in determining birth weight are maternal health complications during pregnancy and abnormal health conditions of the infant at birth. In previous research, maternal health characteristics that have been shown to be determinants of low birth weight include parity, prior birth outcomes, hypertension, gestational and regular diabetes, and infections, such as pelvic inflammatory disease and other sexually transmitted infections (Kallan 1993; Ricketts, Murray and Schwalberg 2005). Parity is important because mothers having a previous low birth weight infant have a higher risk of having another low birth weight infant. Results from several studies addressing this relationship indicate that maternal health complications and birth weight vary by race and socioeconomic status (Geronimus and Bound 1990; Samuels 1986). Many of the health conditions that mothers experience prior to or during pregnancy can lead to the premature birth of the infant, increasing the risk that the infant will also be low birth weight. Similarly abnormal health conditions of the infant can develop in utero due to biological characteristics of the mother and father or due to behavioral characteristics of the mother, such as smoking (Ricketts, Murray and Schwalberg 2005). Many abnormal health conditions of the infant that can lead to an infant being born of lower birth weight than otherwise healthy infants are due to developmental problems during pregnancy.

Each of the biological characteristics detailed above has consistent relationships with birth weight. Premature and multiple birth infants are at a much higher risk of having lower birth weights. This finding is consistent across racial groups and socioeconomic differences. Maternal health conditions and abnormal health conditions of the infant are more sensitive to social and behavioral characteristics of individuals. These characteristics are detailed next as they relate to birth weight.

**Social Characteristics**

*Socioeconomic Status*

Higher levels of socioeconomic status have been shown to improve health outcomes. One of the most consistent hypotheses in the socioeconomic status and health literature, the absolute-income hypothesis, supports the idea that at the individual level, higher income is associated with better health outcomes (Lynch and Kaplan 2000). Specifically, the absolute-income hypothesis states that the health of an individual depends on their own individual level of income, regardless of the income of individuals around them (Kawachi, Subramanian and Almeida-Filho 2002). The relationship established in this hypothesis is found for a variety of adult morbidity and mortality patterns, but less work has been devoted to the relationship between socioeconomic status and infant and child health outcomes.

In support of the absolute-income hypothesis, research indicates that health outcomes improve as an individual's socioeconomic status increases (Blane, Davey Smith and Bartley 1993; Frisbie et al. 2004; Leon 2001). And, while recent research may indicate that the relationship between SES and health is curvilinear (Ecob and Davey Smith 1999), the fundamental relationship between measures of socioeconomic status and health persists (Finch 2003a; Link and Phelan 1995). Further Link and Phelan (1995) indicate that while mediating or proximate causes for health differentials and varying health outcomes may change over time, the relationship between socioeconomic status and health persists for various outcomes and behaviors. The gradient observed between socioeconomic status and health also lends support to the general conclusion that socioeconomic disadvantage precedes poor health status (Blane, Davey Smith and

Bartley 1993), which could have important implications for infant health outcomes. Infants born into a family with low income may experience poor health outcomes due to the transfer of the family's socioeconomic position to the infant.

Fewer studies have addressed the shape or existence of a SES gradient for child or infant health. Some studies have addressed this relationship for adolescents (Brooks-Gunn, Duncan and Britto 1990; Case, Lubotsky and Paxson 2002; Goodman 1999), and more recent research tests this relationship for infant health and SES indirectly (Conley and Bennett 2000, 2002; Finch 2003a). Chen, Matthews and Boyce (2002) indicate that there are socioeconomic differentials in child and adolescent health and behavioral outcomes, and that SES gradients may appear as early as birth. Their argument states that if socioeconomic status gradients are observed for women's health, it is plausible that the socioeconomic characteristics of the mother are passed on to their infants. Numerous measures of socioeconomic status have been employed to look at the relationship between SES and birth weight. However, maternal educational levels and household income levels produce the most stable relationships with birth weight.

*Education*

Mother's years of completed education at the time of the infant's birth is the most common type of socioeconomic status measure used in the infant health literature (see Boardman et al. 2002; Carlson 1984; Finch 2003b; Kramer et al. 2000; O'Campo et al. 1997; Sable et al. 1997; Stuber at al. 2003), while father's education is used less often (Finch 2003b). Mother's education is probably the most commonly used measure of SES, because its estimates are stable and this measure seems to capture the other components included in the concept of socioeconomic status, such as income and occupation (Bloomberg, Meyers and Braverman 1994; Kramer et al. 2000). Studies find that women with lower educational levels are more likely to have a low birth weight infant. Having a high school diploma may be an important measure of maternal education, because economic outcomes tend to be better for high school graduates compared to those individuals that do not complete high school (Conley and Bennett 2000). Education may signify acquired knowledge and the ability to manage the social system to achieve a certain goal. Educational levels are also closely related to lifestyle choices and behaviors (Backlund, Sorlie and Johnson 1999). Therefore, higher levels of maternal education should lead to more favorable infant health outcomes and healthy birth weights.

*Income*

Household income is used to capture another dimension of socioeconomic status in studies of infant health. Measures of household income generally include income from all sources and members of the family (Conley and Bennett 2000; Stuber et al. 2003). Various transformations of this variable are used since the shape of the relationship between health and income is nonlinear (see Rogers, Hummer and Nam 2000; Royston and Altman 1994). Most often additional gains in income for individuals with relatively low household income are beneficial to health outcomes, but after reaching a certain level of income additional gains do little to improve health status. Income represents social and material resources, potential access to different lifestyles and environments, and security (Backlund, Sorlie and Johnson 1999). In the case of low birth weight, low incomes are thought to be related to poorer nutrition and decreased access to health care and prenatal care during pregnancy (Alexander and Korenbrot 1995: Chowitz, Cheung and Lieberman 1995; Hughes and Simpson 1995; Kramer 1987).

A recent study by Conley and Bennett (2000) indicates that when investigating income gradients in an ongoing panel study, no effects of income are found for the probability of determining the low birth weight status of infants. This finding suggests that the probability of being born low birth weight exhibits a threshold effect. Most studies incorporating a measure of household income find that infants in families with lower incomes are more likely to be born low birth weight. However variation in birth weight is not associated with income levels.

Most important to note about these two measures of SES is that individuals faring poorly on measures of socioeconomic status are more likely to have infants with poor health outcomes. These general findings support the work by Chen, Matthews, and Boyce (2002) suggesting that the socioeconomic status of the mother is passed to her infant. Higher levels of education and income give a knowledge base and set of resources that make choices about health decisions more accessible and easier to understand. Higher levels of SES also generally afford women better overall lifestyles and behavioral choices. Mothers with less education and few economic resources are disadvantaged because they have less access to the social, economic, and political systems that allow for more freedom in choices and behaviors, such as having a healthy and balanced diet, receiving prenatal care, and avoiding behaviors such as smoking and consuming alcohol while pregnant. Therefore, higher levels of education and higher incomes will be associated with higher individual birth weights.

*Health Insurance*

Insurance status is often included in studies looking at infant health, because access to health care may prevent poor health outcomes. Insurance status of the mother may be an indirect measure of her socioeconomic status, and is related to the employment status and job quality of the mother and/or her partner. Various forms of insurance are included in the literature, but Medicaid seems to be the predominant form of insurance specifically mentioned (see Bird et al. 2000; Sable et al 1997; Sable and Wilkinson 2000). Results from these studies indicate that parents using Medicaid are more likely to have an infant born low birth weight. Most likely this is associated with the low incomes of those who qualify for Medicaid, and more likely represents a spurious relationship between participation in Medicaid and low birth weight.

*Maternal Age*

Maternal age at the time of birth has a significant relationship with birth weight. Women under the age of 18 or over 34 are more likely to have a low birth weight infant (Conley and Bennett 2000). In order to account for the shape of this relationship, a non-linear function of age is often included in studies examining maternal age and birth weight. However, Rosenzweig and Wolpin (1995) found that young maternal age has a positive relationship with overall birth weight when family background is controlled. When continuous measures of age are incorporated in models examining birth weight, an inverse U-shaped relationship is usually observed. This relationship usually disappears with the inclusion of sociodemographic variables (Kallan 1993). Studies focusing on infant mortality rates find that infants of older mothers have a higher probability of surviving the first year of life than infants born to young mothers (Machado and Hill 2005). Still the relationship between maternal age at birth and low birth weight remains.

*Race*

Race and ethnicity have been prominent characteristics used to explain the disparities that exist in birth weight (James 1993; Shiono et al. 1997). In the United States, the largest disparities in birth weight are observed between blacks and whites, with Hispanics faring well compared to whites. More research needs to consider other racial and ethnic groups, such as Native Americans, when trying to understand the disparities that exist in birth weight status based on race (Munroe et al. 1984; Thomson 1990). Maternal race/ethnicity is included in almost all analyses looking at birth weight and other infant health outcomes. These studies indicate that blacks are much more likely to have low birth weight infants even with SES and other individual factors controlled. A better understanding of other maternal characteristics, biological differences by race, and larger structural factors may help to explain why racial disparities persist once controls for socioeconomic status and other individual-level measures are considered. Differences based on behavioral mechanisms may offer some insight into why individuals of certain racial groups are at an increased risk of having poor infant health outcomes.

*Marital Status*

Marital status, a measure of family structure and social support, is an important social characteristic also mentioned in the infant health literature. The relationship between marital status and birth weight probably operates through the wantedness of the pregnancy, behavioral characteristics such as smoking and consuming alcohol, and prenatal care (Kallan 1993). Albrecht, Miller, and Clarke (1994) indicate that women living with the father of their child receive more support and are less likely to engage in risky behaviors while pregnant, leading to better health outcomes for the infant.

A mother being married at the time of her infant's birth has been identified as an important protective factor against low birth weight and infant morbidity and mortality (MacDorman and Atkinson 1999). Bennett (1992) finds that unmarried women are at double the risk of having a low birth weight infant compared to married women. Bird and colleagues (2000) have looked further into this relationship and indicate the relationship type and duration may be more important than the actual marital status of the mother. However martial status is an influential measure of the life circumstances and social network the infant is born into and may impact future morbidity patterns of the infant and the parents.

Relationships discussed thus far between biological and social characteristics of infants and their mothers with birth weight are fairly stable across studies. However, the introduction of behavioral characteristics into many models examining birth weight indicates that variation in individual birth weights and the probability of low birth weight status may differ based on these biological and social characteristics. Important individual-level behavioral characteristics in determining birth weights are detailed below.

## Behavioral Characteristics

### *Cigarette Smoking and Alcohol Consumption*

Smoking is the most common maternal behavioral characteristic mentioned in relation to infant health outcomes. Studies incorporating smoking during pregnancy as a variable to predict infant health outcomes indicate that smoking has negative effects on infant health and is related to low birth weight among infants. Smoking behavior of pregnant women has been found to have one of the strongest relationships with low birth weight and other infant health complications. A variety of morbidity patterns, such as asthma and respiratory illnesses, are related to the mother smoking during pregnancy (Finch 2003b; Kallan 1993, McCormick 1985; Petrou 2005; Sable and Wilkinson 2000). Of all behavioral mechanisms operating at the individual-level, smoking has been acknowledged to be the largest modifiable risk factor for low birth weight (Shiono and Behrman 1995).

Alcohol consumption has been associated with birth weight largely by its connection to fetal alcohol syndrome. Yet results indicate that women consuming alcohol during pregnancy have infants with lower overall birth weights compared to pregnant women that do not drink (Little 1977). However, many fewer women abuse alcohol during pregnancy compared to those that smoke, and smoking behavior accounts for more of the variation in individual birth weights and the overall risk of having a low birth weight infant (Chomitz, Cheung and Lieberman 1995; Day and Richardson 1991; Larroque 1992; Shiono and Behrman 1995).

*Nutrition*

One key behavioral characteristic mentioned in the infant health literature is maternal nutrition during pregnancy. A healthy maternal diet is closely associated with maternal weight gain, and maternal weight gain is an indirect measure of nutrient intake during pregnancy (Finch 2003a). Weight gain during pregnancy is largely shaped by maternal dietary patterns, weight and height prior to pregnancy, the length of gestation, and the overall size of the fetus (Chomitz, Cheung and Lieberman. 1995). Therefore, low or inadequate weight gain during pregnancy may reflect poor nutritional status. Kramer (2003) finds that much of the risk of having a low birth weight infant is associated with low pre-pregnancy body mass and low maternal weight gain. This finding indicates that healthy pre-pregnancy weight and maternal weight gain may be important for decreasing the risk that an infant will be born low birth weight. Prenatal health, nutrition, and healthy weight gain during pregnancy may serve as proxies for healthy nutrition patterns for infants early in life, leading to better birth weights and better nourished infants and children.

Access to fresh food prior to and during pregnancy is also a concern for the overall nutrition status of the infant. One program helping to reduce the risk of having a low birth weight infant for low income mothers is the Women, Infants, and Children (WIC) supplemental food program (Finch 2003a). WIC is a means-tested program available to low income women. Participation in WIC has been shown to eliminate variation in low birth weight due to differences in income (Brien and Swann 2001; Finch 2003a; Moss and Carver 1998). Length of participation and onset of participation once becoming pregnant have been important control variables in these studies. Results from studies examining birth weight and WIC participation should be interpreted with caution as selection into the program and access to places offering WIC may bias findings (Basrur, Makarchuk and Kramer 1999; Buescher and Horton 2001). Access to quality foods while pregnant is beneficial to the overall birth weight of the infant.

*Wantedness*

Much debate exists over the relationship between pregnancy wantedness and birth weight (Laukaran and van den Berg 1980; Marsiglio and Mott 1988; Morris, Udry and Chase 1973). If pregnancy wantedness does have a relationship with birth weight it is likely to operate through smoking behavior (Weller, Eberstein and Bailey 1987), stress, and prenatal care use (Marsiglio and Mott 1988). Women not wanting to be pregnant at the time they conceive may engage in negative behaviors in an effort to cope with the pregnancy. Pregnancy timing and birth order may also influence wantedness and operate through these other mechanisms to influence birth weights (Kallan 1993). Still this relationship needs to be examined further to understand the individual behavioral dynamics that may impact birth weights if a pregnancy is not wanted.

Relationships detailed above between birth weight and biological, social, and behavioral characteristics of mothers and infants are consistent in the literature. These relationships also help to explain much of the variability in birth weights. However, these individual-level measures are not likely to explain all of the variability that exists in birth weights. Moreover, the health status of adults and infants is not solely determined by individual factors.

To better understand differences in birth weights across places in the U.S., a multidimensional framework incorporating structural-and individual-level correlates of birth weight is needed. This multidimensional framework was presented above, and the importance of inequality across places lends better insight into reasons why individuals may experience risks for low birth weight that vary based on their geographic location. While the relationship between socioeconomic status and health is one of the more prominent in the public health literature, individuals with low incomes living in areas with equitable income distributions should fare better on infant health outcomes than low income individuals living in areas with extreme levels of inequality. This difference in health outcomes for individuals with similar incomes would be due to the social, economic, and political structures available to most individuals living in areas with little inequality, while low income individuals or minorities living in highly inequitable areas would be segregated from access to such resources. Based on the multidimensional framework presented above, research questions are developed to understand the inequality-birth weight relationship. These questions are presented below.

## Research Questions

Determinants of population health operate at multiple levels. By only examining individual- or structural-level characteristics, the relationships established offer little insight into the variability that exists in birth weights for individuals situated in a specific geographic context. In order to frame both the individual- and structural-level factors that influence birth weights, theoretical explanations at both levels have been detailed above, along with a discussion of the spatial nature of inequality. This framework presents a new way to examine infant health outcomes, specifically birth weights, that takes account of the multidimensionality of inequality and how the spatial patterning of economic inequality can influence individual health risks independent of individual characteristics.

While the absolute-income hypothesis has received much support from individual level studies, results supporting this hypothesis offer little insight into how individual health is affected by the spatial nature of inequality. The relative-income hypothesis begins to extend the individual-level ideas in the absolute-income hypothesis to focus more on the impact of income inequality and the positioning of individuals within a social space in relation to health outcomes. Still these two theories alone explain a very small amount of variation in individual birth weights. A more complete conceptual framework must also address the distribution of resources and infrastructures between places as well as the positioning of individuals within the economic structure based on social class segregation. Therefore, a multidimensional framework for the study of health and inequality distinguishes the effects of both structural- and individual-level measures for determining birth weight. Also the inclusion of multiple levels of rurality as one measure of structural-level characteristics allows for the variability in birth weight by residential location to be better specified and explored.

Chapter 3 explores the individual-level relationships with birth weight by estimating both ordinary least squares multiple regression and logistic regression models. These models more carefully explore the relationships between biological, social, and behavioral measures and birth weight. This chapter helps to frame key individual-level factors in determining variability in individual birth weights and the probability of an infant being born low birth weight. Further race-, sex-, and plurality-specific models lend additional insight into how social and behavioral characteristics of mothers and their infants vary in determining average birth weights or the probability of low birth weight status of specific types of infants. Based on data from the restricted files of the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B), the following research hypotheses will be tested: (1) biological characteristics of mothers and infants will be more important in determining birth weights than social and behavioral characteristics of the mother because biological characteristics are more proximate measures of birth weight; (2) the absolute-income hypothesis will be supported in predicting individual birth weights and the probability of low birth weight status for infants, because higher household income and mother's educational level will be associated with higher birth weight; (3) birth weights will differ based on the race/ethnicity of the infant, plurality status of the birth, and sex of the infant, and not all biological, social, and behavioral characteristics are likely to operate in the same manner; (4) the absolute-income hypothesis is likely to operate in a different manner for different racial/ethnic groups, in that minorities may experience higher birth weights if they are able to maximize higher levels of education and income; and (5) behavioral characteristics suggested in the birth weight literature will reduce the effects of biological or social variables in these models, working through such measures as gestational age, maternal and infant health complications, race, and socioeconomic status.

Chapter 4 builds upon the results in the individual level models in Chapter 3 by incorporating multilevel modeling techniques to capture the spatial context in which infants are born. Special attention is given to the degree of rurality in which infants and their mothers are situated and whether this designation provides additional insight into birth weight differentials. Models in this chapter include structural-level socioeconomic, residential, social capital, social environment, and health service characteristics of the places where these individuals live, along with controls for biological, social, and behavioral characteristics of infants and their families. Merging data aggregated at the county level from the U.S. Census of Population and Housing, County Business Patterns, Uniform Crime Reports, and Area Resource Files with geographical identifiers in the Early Childhood Longitudinal – Birth Cohort, the following research hypotheses are tested in Chapter 4: (1) variation across counties exists in average birth weights and the probability of low birth weight status for infants based on the level of rurality, metro/nonmetro status of the county, and the percentage of the county population that is rural and population density for the county; (2) the addition of other county-level variables will reduce the effect of certain rural-urban continuum code designations; (3) the relative-income hypothesis will be supported, in that the measure of income inequality in the models will have an independent effect on average birth weights and the mean likelihood of low birth weight status for individual infants; (4) minority concentration, measured as the percentage of black and Hispanic residents in the county, will be associated with lower average birth weights; (5) higher levels of social capital will be associated with higher birth weight; (6) a high concentration of medical personnel in the county will have a negative relationship with birth weight; and (7) relationships at the individual level will hold across the multilevel models.

## Conclusion

This chapter has presented a model of geographic differentials in birth weight that incorporates individual- and structural-level characteristics. Detailed theoretical explanations were given at both of these levels in order to more fully capture the multidimensional nature of the risk factors that are associated with birth weight. Taken together these levels of risk are likely to account for behaviors and decisions made prior to and during pregnancy that lead to negative infant health outcomes, but particularly to low birth weight. The following two chapters detail the data and methods used to address the research hypotheses.

# Chapter 3

# Biology and Social Conditions: The Relationship between Individual-Level Characteristics and Birth Weight

## Introduction

This chapter explores variation in individual birth weights and the likelihood of low birth weight status of infants based on social, biological, and behavioral characteristics of mothers and in utero conditions of infants. Birth weight is operationalized as both a continuous and dichotomous measure in order to examine how social, biological, and behavioral characteristics lead to higher or lower birth weights and also determine the odds of having a low birth weight infant. Additionally, race-, sex-, and twin-specific models are examined. These models allow for the biological, social, and behavioral determinants of health to be understood as they relate to specific characteristics of the mother and infant, since these characteristics are hypothesized to differ based on race/ethnicity, sex, and plurality status.

## Data and Methods

### Sample

Data for this analysis are taken from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B), sponsored by the U.S. Department of Education, National Center for Education Statistics (NCES). One of the major goals of this data collection is to have a better understanding of early childhood development, the child's health care, nutrition, and physical well-being (U.S. Department of Education 2005). The ECLS-B follows a nationally representative probability sample of children born between January and December 2001, with over sampling of Asian, Pacific Islander, Chinese, and American Indian children, twins, as well as very low and moderately low birth weight infants. Eventually the study will follow the children from birth until six years of age. A cross-section of the data is used in this analysis and consists of measures from the nine-month wave of data collection.

Children in this data set were sampled from registered births from the National Center for Health Statistics vital statistics system, which reports information from birth certificates (U.S. Department of Health and Human Services 1997)[1]. Primary sampling units (PSUs) and in some cases secondary sampling units (SSUs) were used to sample births, instead of collecting information from hospitals or other birthing places directly. Primary sampling units consist of clusters of adjacent counties. This technique was used in order to control data collection costs and allow for maximum, efficient coverage of the targeted population. Roughly 14,000 cases were sampled leading to 10,688 completed nine-month responses. In eighty of these cases, geographical identifiers were missing, and these cases were eliminated from this analysis leaving 10,608 infants in the final sample.

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[1] Three groups of infants were excluded from the ECLS-B sample. These include children born to mothers less than 15 years of age, children that died before the 9-month assessment, and children that were adopted before the 9-month assessment. All of the children born during the 2001 calendar year were considered for the sample, but the sample only includes infants reaching 9 months of age. This may bias the sample, especially the oversamplng of moderately and very low birth weight infants since they have a much higher risk of dying before reaching nine months of age. Therefore, the low birth weight infants included in this sample are likely to have received quality tertiary health care at birth and to be protected against the biological, social, and behavioral characteristics that lead to the high likelihood of experiencing neonatal infant mortality for very low birth weight infants.

Due to the complex nature of the sampling design, weights are provided in the dataset to obtain correct estimates of standard errors and to make the data generalizable to all infants born in 2001. Weighting variables include a general weight based on the composition of the population; a stratum variable consisting of areas stratified based on race, income, and other characteristics within the primary sampling units; and a primary sampling unit variable consisting of counties using metropolitan statistical area definitions and NCHS health service areas. Together these three weight variables can be used to estimate standard errors using the Jackknife (see Appendix A) or Taylor Series Method of estimation (see Appendix A) (U.S. Department of Education 2005). Incorporation of these estimation techniques is important because estimated coefficients and standard errors are estimated from sample surveys, such as the ECLS-B, and without taking the sampling framework into consideration standard errors will be biased. Further standard errors are a measure of the variance in the estimates associated with the selected sample being one of many possible samples and allow for hypothesis testing and studying group differences. Using inaccurate estimated coefficients and standard errors can lead to the identification of statistically significant results where none are present (U.S. Department of Education 2005). For this analysis, the Taylor series method was used for full sample and logistic regression models, while the Jackknife method was used to estimate race-, sex-, and twin-specific models in order to accommodate sub-populations within the primary sampling unit design.

**Measurement**

Data collected in the first wave (infant nine months of age) include batteries of questions taken from birth certificates, the infants' physical measurements and developmental tests appropriate for nine months of age, and their families, both mothers and fathers, resident and non-resident. Information taken directly from the birth certificates is part of the restricted, or private-use, data file from the ECLS-B and contains sensitive information about infants and their parents. Information included on the birth certificates includes such things as detailed birth weight in grams, gestational age of the infant, plurality status, weight gain during pregnancy, infant and maternal health complications, maternal educational levels, marital status, smoking and drinking behaviors, prenatal care use, and state and county of residence. The detail included on the birth certificates about both infants and their mothers makes the data an ideal source for this analysis. Measures used in this analysis come from birth certificate data and the mother's survey. Since not all social and behavioral characteristics are recorded on the infant's birth certificate, the mother's survey instrument was used to supplement this information, and these measures are detailed below.

*Dependent Variables*

**Birth weight** is used as the key measure to construct both dependent variables in this analysis. On the infant's birth certificate, birth weight in grams is reported. This continuous measure of birth weight is used to indicate how biological, social, and behavioral characteristics are associated with variations in infant birth weights. A composite variable is also available in the ECLS-B, based on the birth certificate data, that categorizes birth weights into normal birth weight (2500 plus grams, or 5.5 pounds plus), moderately low birth weight (between 1500 and 2500 grams, or between 3.5 and 5.4 pounds), and very low birth weight (less than 1500 grams, or less than 3.4 pounds). For the second part of this analysis, the moderately low and very low birth weights categories are combined to create a low birth weight variable, making a dichotomous dependent variable for the low birth weight status of the infant. Therefore, birth weight in grams and a dichotomous measure of low birth weight status serve as the dependent variables in this analysis.

*Independent Variables*

*Biological Characteristics*

Biological measures of the infant and mother used in this analysis include the infant's sex, gestational age in weeks, plurality status, maternal health complications during pregnancy, and abnormal health conditions of the infant at birth. **Sex** of the infant is reported on the birth certificate and is measured as a dichotomous measure with 1 representing males and 0 representing females. **Gestational age** is also reported on the birth certificate of the infant and is measured as a continuous value of gestational age in weeks. The time of gestation is computed by the date of birth of the infant and the last normal day of menses, imputed from the last menstrual cycle date, or based on the clinical estimation of gestation, depending on the information available and used per state. **Plurality status** of the birth is a dichotomous measure of whether or not the infant was born as a singleton or twin. A value of 1 indicates a twin, and a value of 0 represents single births.

A variety of health complications are combined to make a measure of **maternal health complications** during pregnancy. These consist of the following risk factors included on the infant's birth certificate: anemia, cardiac disease, acute/chronic lung disease, diabetes, genital herpes, (oligo)hydramnios, hemoglobinopathy, chronic hypertension, hypertension during pregnancy, eclampsia, incompetent cervix, previous birth weighing 4,000 or more grams, previous preterm or small birth, renal disease, rh sensitization, uterine bleeding, and other medical risk factors. These measures were combined into one dummy variable capturing the mother's health risk factors during pregnancy (U.S. Department of Education 2005). The mother has a value of 1 if she has any of these complications and a 0 if she has none. Abnormal health conditions of the infant at birth are also based on a variety of health problems combined to make a measure of **newborn health conditions**. Abnormal conditions of the infant are reported on the birth certificate and include the following conditions: anemia hematocrit less than 39/hemoglobin less than 13, birth injury, fetal alcohol syndrome, hyaline membrane disease, meconium aspiration syndrome, assisted ventilation needed for less than 30 minutes, assisted ventilation needed for 30 minutes or more, seizures, and all other conditions (U.S. Department of Education 2005). A dummy variable is created based on these conditions and an infant is assigned a 1 if they experience any of these conditions and a 0 if not.

*Social Characteristics*

Variables used to measure social characteristics of the mother and infant are taken from the birth certificate data and mother's survey. **Mother's education** is reported in detail on the infant's birth certificate and includes 17 categories ranging from no formal schooling to five years or more of college. These categories are collapsed to construct three measures of maternal education and include less than a high school education, high school completion, and some college or more. Three dummy variables are constructed from these measures, and less than a high school education is used as the reference category for the other two educational levels. **Income** is measured as household income from all sources. The ECLS-B reports this variable as a composite measure with thirteen categories[2]. Since this categorization scheme does not accurately reflect differences in income from category 1 to category 13, midpoints of the dollar value of each category are used to create a more continuous measure of income in this analysis. **Health insurance** is a dummy variable that measures whether or not the mother had private health insurance during her pregnancy. Private health insurance includes plans from employers, the workplace, private purchase, or through a state or local government program or community based program. This measure is coded 1 for those women with health insurance and 0 for those without any coverage and is reported in the mother's survey.

**Mother's age at birth** is reported on the infant's birth certificate and indicates the mother's age at the time of delivery in years, a continuous measure. Since the shape of the relationship between mother's age and birth weight is nonlinear, a squared term is added to this analysis to more accurately reflect the shape of the relationship. **Mother's age of birth squared** is simply measured as the mother's age at birth squared. **Race/Ethnicity** is reported on the infant's birth certificate. The race/ethnicity of the mother is used to measure this characteristic, since the race of the mother is assigned to

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[2] Income consists of the following categories: 1=$5,000 or less; 2=$5,001 to $10,000; 3=$10,001 to $15,000; 4=$15,001 to $20,000; 5=$20,001 to $25,000; 6=$25,001 to $30,000; 7=$30,001 to $35,000; 8=$35,001 to $40,000; 9=$40,001 to $50,000; 10=$50,001 to $75,000; 11=$75,001 to $100,000;12=$100,001 to $200,000; and 13=$200,001 or more.

the infant at birth. Dummy variables are created for whites, blacks, Hispanics, Asians, and those of other and multiple races. The racial category for other and multiple races includes Native Americans. In this set of analyses, whites are used as the reference category. The final social characteristic in this analysis is a measure of maternal **marital status**. This measure is taken from the infant's birth certificate and is a dummy variable that indicates if the mother is married or not at the time of birth.

*Behavioral Characteristics*

Behavioral characteristics are the final set of measures used in this analysis. Mother's **smoking** and **drinking** behaviors during pregnancy are reported on the infant's birth certificate. Both are dichotomous measures for whether the mother smoked cigarettes or consumed alcohol during her pregnancy. A value of 1 is assigned to the behavior if the mother smokes or drinks, while a value of 0 is give to the behavior if she does not. The total **number of prenatal visits** the mother made during her pregnancy is also reported on the infant's birth certificate. This is a continuous measure representing the total number of visits she makes. Mother's **weight gain** during pregnancy is a continuous measure reported on the infant's birth certificate. Healthy weight gain during pregnancy is estimated to start at twenty-five pounds, but between thirty-five and forty pounds is a healthy amount of weight to gain during pregnancy (American Pregnancy Association 2003). The measure used for weight gain has three values. Weight gain of less than twenty-five pounds is assigned a zero, between twenty-five and thirty-four pounds is assigned a one, and weight gain over thirty-five pounds is assigned a two.

Food security, pregnancy wantedness, and WIC usage make up the remaining behavioral characteristics. Mother's are asked during their survey if their household had access to plenty of fresh foods during her pregnancy. **Food security** is a dichotomous measure indicating if the mother reported the household to be food secure or not. The measures for **pregnancy wantedness** are based on a question from the mother's survey that asked the mother if she wanted to have a baby at the time she became pregnant. She could respond yes, no, or not sure. Three dummy variables were constructed from this response and include the mother wanted the pregnancy (reference category), the pregnancy was not wanted, or the mother was unsure about the wantedness of the pregnancy at the time she became pregnant with the child. The final measure in this analysis captures **WIC** usage while pregnant. Mothers were asked if they used the supplemental WIC program during their pregnancy. This is a dichotomous measures coded 1 for yes and 0 for no. Methods used to incorporate these variables into models examining birth weight are detailed below.

**Methods**

The analytic methods employed in this chapter are as follows. First I estimate multiple regression models of individual birth weight for all infants in the ECLS-B using nested models. The full model is estimated both with and without design effects. Next I examine race-, sex-, and twin-specific models using multiple regression techniques in order to test whether the biological, social, and behavioral factors operate in the same manner across race/ethnicity groups, for male and female infants, and for twins versus singleton births. Statistical analyses are conducted to test for significant differences across these groups. Jackknife estimation techniques are used for this set of analyses in order to account for the design effects of the data. This technique adjusts the standard errors and reflects the true population composition sampled in the dataset. By using multiple regression techniques, results from these models are useful in determining how biological, social, and behavioral characteristics are associated with variation in birth weights.

In the next set of analyses, each of these models is re-estimated using a dichotomous dependent variable of low birth weight status (less than 2,500 grams) or not. Logistic regression techniques are used to evaluate how biological, social, and behavioral characteristics of mothers and infants are associated with the odds of being born low birth weight. Overall this analysis contributes to the literature by exploring more comprehensive biological, social, and behavioral characteristics of mothers during pregnancy and infants at birth and offers insight into how these characteristics correspond with the low birth weight status of individual infants. Further the race-, twin-, and sex-specific models delve more deeply into how these measures operate differently for different types of infants. In addition the comparison of weighted and unweighted models offers methodological support for using weights to account for sample selection in large national datasets.

## Findings

### Characteristics of Individuals in the ECLS-B

As mentioned above, the ECLS-B oversampled certain racial groups, twins, and moderately low and very low birth weight infants. Table 3.1 presents the distribution of racial groups, twins, and low birth weight infants as well as the total number and percentage of individuals sampled in the ECLS-B and found in the population of births for 2001. The largest oversampling for racial groups involved Asians (13.7 percent), Native Americans (3.2 percent), and those individuals of other or multiple races (2.6 percent).

Table 3.1: Distribution of Racial Groups, Twins, and Low Birth Weight Infants in the Early Childhood Longitudinal Study – Birth Cohort, n=10,608

| *Racial Groups* | Percent in Sample Unweighted | Number in Sample | Percent of Births in Population, 2001 | Number of Births in Population, 2001 |
|---|---|---|---|---|
| White | 46.2 | 4,861 | 58.3 | 2,326,645 |
| Black | 16.4 | 1,723 | 13.6 | 542,751 |
| Hispanic | 17.9 | 1,887 | 21.9 | 873,988 |
| Asian | 13.7 | 1,445 | 3.4 | 135,688 |
| Native American | 3.2 | 342 | 0.6 | 23,945 |
| Other/Multiple Races | 2.6 | 273 | 2.2 | 87,798 |
| | | | | |
| *Twin Status* | | | | |
| Twins | 15.5 | 1,643 | 2.9 | 117,401 |
| Singletons | 84.5 | 8,965 | 97.1 | 3,873,413 |
| | | | | |
| *Birth Weight Status* | | | | |
| Low Birth Weight | 26.6 | 2,753 | 7.5 | 294,754 |
| Normal Birth Weight | 73.4 | 7,855 | 92.5 | 3,696,060 |

Whites constitute the largest racial group, 46.2 percent in the sample and 58.3 percent in the population of births. Blacks are slightly oversampled in the ECLS-B, with blacks constituting 16.4 percent of the sample while 13.6 percent are in the population, while Hispanics account for 17.9 percent of the ECLS-B sample. As for the other minority groups, Asians represent 3.4 percent of the population of births, Native Americans constitute 0.6 percent of the population of births, and individuals of other races/ethnicities or multiple races account for 2.2 percent of the population of births. Native American births and those of other races or multiple races account for a sizable number of births in the population, 23,945 and 87,798, respectively.

Twins are heavily oversampled in the ECLS-B, making up 15.5 percent of the sample as opposed to 2.9 percent of the population of births. In the ECLS-B, twins are the only multiple birth group selected, so triplets or larger multiple births are not included in the sample. While the total number of twins in the population of births is somewhat small, the oversampling of twins allows for more analysis to focus on differences and similarities between these pairs. Low birth weight infants also are oversampled. Both moderately low and very low birth weight infants are combined in the low birth weight category and constitute 26.6 percent of the sample of births compared to 7.5 percent of all births in 2001. When proper weights and design effects are taken into consideration, results using these data will account for the sample design and provide more robust standard errors. Therefore oversampling of low birth weight infants in the sample does not skew the results when methods adjusting for sample selection are used.

Table 3.2 shows the percentage or mean and standard deviations for all variables used in this individual-level analysis. All values in this table are weighted. The weighted mean birth weight is 3,319.13 grams, which is equivalent to about 7.30 pounds. As for the dichotomous measure of low birth weight, approximately 7.4 percent of all births in 2001 results in an infant being born low birth weight. This includes moderately low and very low birth weight infants.

Almost 51 percent of infants are males, and this is consistent with sex ratio at birth trends for the US (Matthews and Hamilton 2005). Similar to values presented in Table 3.1, twins make up almost 3 percent of births. Gestational age, with a mean of 38.77 weeks, is consistent with normal pregnancy durations of 38 weeks, or 277 days. Two other important biological measures presented in Table 3.2 include maternal health complications during pregnancy and abnormal health conditions of the infants at birth. Roughly twenty-nine percent of mothers experience some type of pregnancy-related complication, while almost seven percent of infants are born with an abnormal health condition.

Descriptive statistics for social characteristics are presented next in Table 3.2. The majority of women, 47.68 percent, have some college education or more. A little more than thirty percent of mothers only have a high school education, while almost twenty-two percent of mothers have less than a high school education. Household income has a mean value of $50,273.97 in 2000 dollars. Adjusted to 2004 dollars, the mean household income of ECLS-B families is $55,120. This value is close to the mean household income in the U.S. for 2000 in 2004 dollars of $57,135 (U.S. Census Bureau 2004a). A little more than half of the families have access to health insurance (53 percent). The mean age at child birth in the sample is 27.32 years old. Racial distributions are the same as those presented in Table 3.1. The majority of women are married, with 67.5 percent of women married when they give birth to their child.

Only a small percentage of women smoke or consume alcohol while they are pregnant. Table 3.2 shows that 10.8 percent of women smoke while they are pregnant and 0.43 percent of pregnant women consume alcohol. Women tend to have 11.53 prenatal visits while pregnant. Most women feel they have plenty of food in their homes (89.9 percent say they are food secure). The vast majority of women also want to be pregnant with their child at the time that they conceive. Only about nine percent of women did not want to become pregnant and almost seven percent are not sure about the wantedness of the pregnancy at the time that they conceived. Less than half of pregnant women use WIC (40.26 percent) to feed themselves and other children in their household while they are pregnant

Table 3.2: Weighted Percentages, Means and Standard Deviations for Individual-Level Models, Early Childhood Longitudinal Study – Birth Cohort, n=10,608

| | Percentage | Mean | Standard Deviation |
|---|---|---|---|
| *Dependent Variables* | | | |
| Birth Weight | | 3,319.13 | 874.40 |
| Low Birth Weight (1=yes) | 7.39 | | |
| *Independent Variables* | | | |
| **Biological Characteristics** | | | |
| Child Sex (1=male) | 51.05 | | |
| Gestational age (weeks) | | 38.77 | 3.91 |
| Twin (1=yes) | 2.94 | | |
| Maternal Complications | 29.35 | | |
| Newborn Conditions | 6.53 | | |
| **Social Characteristics** | | | |
| Mom Less than High School (reference) | 21.19 | | |
| Mom High School | 31.13 | | |
| Mom College or More | 47.68 | | |
| Income | | 50,273.97 | 635.97 |
| Health Insurance (1=yes) | 53.02 | | |
| Mother's Age at Birth | | 27.32 | 6.36 |
| Mother's Age at Birth Squared | | 784.71 | 40.45 |
| White (reference) | 58.30 | | |
| Black | 13.60 | | |
| Hispanic | 21.92 | | |
| Asian | 3.42 | | |
| Other | 2.76 | | |
| Married (1=yes) | 67.50 | | |
| **Behavioral Characteristics** | | | |
| Smoke while Pregnant | 10.82 | | |
| Drink while Pregnant | 0.43 | | |
| Number Prenatal Visits | | 11.53 | 4.32 |
| Weight Gain – Less than 25 Pounds (ref) | 44.20 | | |
| Weight Gain – 25 to 34 Pounds | 29.06 | | |
| Weight Gain – 35 Pounds or More | 26.74 | | |
| Food Secure (1=yes) | 89.91 | | |
| Pregnancy Wanted (reference) | 84.48 | | |
| Pregnancy Not Wanted | 8.87 | | |
| Pregnancy Not Sure | 6.65 | | |
| WIC (1=yes) | 40.26 | | |

**The Relationship of Biological, Social, and Behavioral Characteristics to Birth Weight**

Descriptive statistics from the previous section indicate that most of the women giving birth are fairly healthy, give birth to infants of normal birth weight, have high levels of education, decent household income levels, and most have social support in the form of marriage, even though a measure of the quality of this union is not available in the ECLS-B (Albrecht, Miller and Clarke 1994; Bird et al. 2000). This section explores how biological features of the infant and mother as well as social and behavioral characteristics of the mother are associated with birth weight. These models use basic assumptions of linear multiple regression, such as independence among observations and normally distributed random errors, and report how these variables lead to higher or lower birth weights. Both unstandardized and standardized coefficients are presented in the models, because standardized coefficients are directly comparable to one another and indicate which individual-level characteristics have the greatest influence on birth weight. The first set of results presents nested models with the variables just described from Table 3.2 with adjustments for weighting and design effects. Next the full model with weighting and design effects is compared with the full model only with weighting and then to the full model without design effects to show the variation in findings when the sampling framework and design effects are taken into consideration.

Table 3.3 presents the multiple regression results of biological, social, and behavioral characteristics and their association with birth weight in grams using the Taylor series method of estimation to account for design effects and sample selection in the ECLS-B. Model 1 in Table 3.3 presents all of the biological characteristics in this

Table 3.3: Individual Models of Birth Weight with Design Effects, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
The first value in each column is the unstandardized coefficient, while the values in parentheses are the standardized coefficient values.

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| **Biological Characteristics** | | | | | |
| Child Sex (1=male) | 124.39 (0.07)** | 123.69 (0.07)** | 125.53 (0.07)** | 123.85 (0.07)** | 124.16 (0.07)** |
| Gestational age (weeks) | 107.97 (0.48)** | 107.19 (0.48)** | 106.27 (0.47)** | 106.01 (0.46)** | 102.16 (0.45)** |
| Twin (1=yes) | -589.64 (-0.24)** | -608.70 (-0.25)** | -619.70 (-0.25)** | -619.53 (-0.25)** | -649.18 (-0.27)** |
| Maternal Complications | -34.64 (-0.02)* | -33.06 (-0.02)* | -33.80 (-0.02)* | -28.20 (-0.02)† | -39.29 (-0.02)* |
| Newborn Conditions | -148.09 (-0.05)** | -147.17 (-0.05)** | -152.60 (-0.06)** | -152.24 (-0.06)** | -153.67 (-0.06)** |
| **Social Characteristics** | | | | | |
| *Socioeconomic Status* | | | | | |
| Mom High School (ref=less than HS) | | 15.47 (0.01) | 0.29 (0.01) | -9.85 (-0.01) | -15.25 (-0.01) |
| Mom College or More | | 58.47 (0.01)** | 21.79 (0.02) | -4.28 (-0.02) | -17.42 (-0.03) |
| Income | | 0.0007 (0.05)** | 0.0003 (0.02)† | 0.0002 (0.02) | 0.0002 (0.01) |
| Health Insurance (1=yes) | | 78.37 (0.05)** | 43.50 (0.03)* | 37.73 (0.02)* | 36.73 (0.02)* |
| *Sociodemographics* | | | | | |
| Mother's Age at Birth | | | 24.84 (0.20)* | 27.30 (0.20)** | 28.42 (0.20)** |
| Mother's Age at Birth Squared | | | -0.34 (-0.16)* | -0.38 (-0.16)* | -0.37 (-0.15)* |
| Black (reference=white) | | | -142.05 (-0.06)** | -172.46 (-0.07)** | -157.51 (-0.07)** |
| Hispanic | | | -18.59 (-0.01) | -55.77 (-0.03)* | -28.23 (-0.01) |
| Asian | | | -206.18 (-0.08)** | -226.74 (-0.09)** | -193.18 (-0.08)** |
| Other | | | -116.32 (-0.02)* | -108.02 (-0.02)* | -86.36 (-0.02)* |
| Married (1=yes) | | | 29.06 (0.02) | 15.83 (0.01) | 21.32 (0.01) |
| **Behavioral Characteristics** | | | | | |
| Smoke while Pregnant | | | | -176.63 (-0.06)** | -186.81 (-0.07)** |
| Drink while Pregnant | | | | | -21.83 (-0.002) |
| Number Prenatal Visits | | | | | 4.79 (0.02)* |
| Weight Gain | | | | | 85.49 (0.08)** |
| Food Secure (1=yes) | | | | | 3.96 (0.002) |
| Pregnancy Not Wanted (ref=wanted preg) | | | | | 7.42 (0.002) |
| Pregnancy Not Sure | | | | | 36.99 (0.01) |
| WIC (1=yes) | | | | | 10.03 (0.004) |
| Intercept | -893.94 (0.18)** | -970.89 (0.18)** | -1273.24 (0.15)** | -1234.49 (0.15)** | -1257.18 (0.14)** |
| F | 1731.96** | 904.07** | 559.30** | 532.95** | 410.40** |
| $R^2$ | 0.2915 | 0.3067 | 0.3209 | 0.3284 | 0.3414 |

** p ≤.001 * p ≤.05 † ≤.10

analysis. Male infants weigh 124.39 grams more than female infants, controlling for other biological variables in this first model. Each additional week of gestation for the infant leads to an additional 107.97 grams in birth weight. Therefore, preterm infants have a higher chance of being born with lower birth weights. For instance, a female, singleton infant born at 30 weeks of gestation would have a predicted birth weight of 2345.16 grams, or 5.16 pounds (birth weight = -893.94 + (124.39 * 0) + (-589.64 * 0) + (107.97 * 30)), indicating that the infant would be moderately low birth weight. Twins weigh 589.64 grams less than singleton infants, controlling for other variables in Model 1. Both maternal health complications during pregnancy (-34.64) and infant health complications at birth (-148.09) are associated with lower birth weights. Gestational age has the greatest influence on birth weight, with a standardized coefficient value of 0.48. This value indicates that an increase of one standard deviation in gestational age in weeks leads to an increase of 0.48 standard deviation in the infant's weight at birth in grams. Model 1 in Table 3.3 accounts for 29.2 percent of the variation in birth weight in grams.

Measures of socioeconomic status are added in Model 2 of Table 3.3. If the infant's mother has some college education or more, the infant will weigh 58.47 grams more at birth than an infant whose mother has less than a high school education, and this relationship is statistically significant at the $p \leq 0.001$ level. No statistically significant difference in birth weight occurs between mothers with no high school education and those with a completed high school education. Income has a positive significant relationship with birth weight. Health insurance also has an association with higher birth weights, indicating that mothers with some form of private health insurance have infants with birth weights that are 78.37 grams higher than infants of mothers without health insurance. Based on the results in this model, the absolute-income hypothesis, stating that higher levels of income lead to better health outcomes, is supported. Coefficients in this model for biological characteristics of the infants and mothers are similar to those in Model 1. Gestational age remains the strongest relationship with birth weight, with a standardized coefficient of 0.48. Almost thirty-one percent of the variance in birth weight is explained by Model 2.

Mother's age, race/ethnicity[3], and marital status are added in Model 3 of Table 3.3. Each additional year of age of the mother at the time of birth produces higher birth weights (24.84 grams). However a squared term for mother's age at birth is also included in this model and has a statistically significant negative relationship with birth weight, indicating an inverse U-shaped relationship. This means that additional years of age of the mother contribute to higher birth weights until a certain age then additional years of age lead to lower birth weights. This shift occurs at about 37.5 years of age.

Black infants weigh 142.05 grams less at birth than white infants. Asian infants and those infants of other or more than one race also weigh less than white infants at birth, 206.18 and 116.32 grams less, respectively. The relationship between infants of other or multiple race and birth weight is significant at $p \leq 0.05$. There is not a statistically significant difference between Hispanic and white infants in birth weight. The mother being married at the time of birth does not have a statistically significant relationship with birth weight. In Model 3, mother's education is no longer statistically significant in

[3] Models were estimated with the inclusion of Native Americans as a separate race category. Results from these models indicate that there is no statistically significant difference between Native Americans and whites in overall birth weights. The inclusion of Native Americans did not change the significance levels of any of the other variables in the models either. While the study of Native Americans is important when focusing on rural/urban differences in health (Rhoades and Cravatt 2004), no significant differences were observed in this analysis. Therefore Native Americans were included in the Other racial category.

predicting birth weight, and income becomes only marginally significant ($p \leq 0.10$) with the addition of mother's age, race/ethnicity, and marital status. This suggests education and income do not benefit all racial/ethnic groups the same when examining variation in birth weight. This may be due to the correlation between education and income with race/ethnicity in these models. This model explains 32.09 percent of the variation in birth weight.

Literature examining early childhood health indicates that maternal smoking behavior during pregnancy has one of the strongest and most consistent associations with birth weight. Smoking behavior during pregnancy, the behavioral characteristic most associated with low birth weight in the literature, is added in Model 4 of Table 3.3. Smoking while pregnant lowers birth weights by 176.63 grams, controlling for other variables in the model. Household income becomes statistically non-significant with the addition of smoking in this model. Educational levels remain non-significant. Coefficients for black and Asian infants become more negative with the inclusion of this variable as well. Therefore, once smoking behavior is controlled for in the model, the effect of black and Asian race is strengthened, suggesting that racial differences in smoking behavior contribute to lower birth weights for black and Asian infants. Hispanics also have a statistically significant lower birth weight than whites with the inclusion of smoking behavior during pregnancy. This relationship is only found when smoking is added to the model (Model 4). Hispanic infants do not have birth weights that are statistically different from white infants in any of the other models. The standardized coefficient for gestational age in this model continues to be the largest (0.46), indicating that an increase of one standard deviation in gestational age in weeks leads to an increase of 0.46 standard deviations in the infant's birth weight in grams.

Additional behavioral characteristics are added in Model 5 in Table 3.3. Of the remaining variables added in this model, only the number of prenatal visits and weight gain during pregnancy are statistically significant. Each additional prenatal visit is associated with higher infant birth weight by 4.79 grams. A mother gaining between twenty-five and thirty-four pounds during pregnancy has an infant with a birth weight 85.49 grams higher than mothers gaining less than twenty-five pounds during pregnancy. Measures of food security, pregnancy wantedness, and WIC use do not have a statistically significant relationship with individual birth weight in this model. Mother's educational levels, household income, and martial status also are not statistically significant in the full model. Relationships with birth weight for black and Asian infants, as well as infants of other or multiple races, remain with the inclusion of behavioral characteristics in Model 5. As in all of the previous models, gestational age is the most important variable in the model determining the infant's birth weight, with a standardized coefficient value of 0.45. The full model accounts for 34.14 percent of the variation in birth weight.

It is interesting to note that the most important variable in determining overall birth weight in these models is gestational age, a biological characteristic. Another biological characteristic, plurality status of the birth, is the second most important variable in determining the birth weight of the infant. However, the social and behavioral characteristics of the mothers tell the most interesting story about variation in birth weights. Race remains an important variable in Models 3, 4, and 5 in Table 3.3. Blacks, Asians, and those of other or multiple races have infants weighing significantly less than white infants, while the birth weights of Hispanic infants are not significantly different from whites except when smoking behaviors are added to the model. Neither maternal educational levels nor household income are statistically significant in determining individual birth weights when all variables are included in the model, lending no support for the absolute-income hypothesis. However, measures of socioeconomic status, in this case household income and maternal education, may be operating through race/ethnicity which have more of a direct effect on birth weight.

The key behavioral variable in determining lower birth weights for infants is the smoking behavior of the mother. Infants born to mothers that smoke during the pregnancy, on average, weigh less than those infants whose mothers do not smoke. Hispanics are also found to have lower birth weights than whites with the inclusion of smoking behavior. Once smoking behavior is controlled in the model, birth weights for black, Asian, and Hispanic infants are lower suggesting that higher prevalence of smoking among whites is associated with lower birth weight of white infants. Another interesting dimension about the behavioral measure of smoking is that it negates the relationship in previous models of household income and birth weight. Smoking during pregnancy therefore changes the relationships with birth weight of other social characteristics included in these models.

**Design Effect Differences in Predicting Birth Weight**

Models in Tables 3.3 were estimated using methods that account for the sampling framework used in collecting data for the ECLS-B, therefore estimating true effects for the population of infants born in 2001 and adjusting the standard errors to account for the sampling design. When design effects are not taken into consideration, the magnitude of these relationships is often underestimated, or statistically significant relationships are found to be significant due to reduced standard errors. Table 3.4 presents results of the full model (Model 5 in Table 3.3) estimated with weighting and design effects (Model 1), weighting without design effects (Model 2), and without weighting or design effects (Model 3).

Models 1 and 2 in Table 3.4 have the same coefficients since both models are weighted to reflect the population composition for 2001. However, standard errors are different for the two models since Model 2 does not account for design effects in the ECLS-B. In comparing the two models, statistically significant relationships are found for all of the same variables in both models. The large sample size may reduce the chance of observing substantial changes in standard errors when design effects are considered. Coefficients and standard errors are different when comparing Models 1 and 2 to Model 3. Model 3 is estimated without weighting or design effects, and results from t-tests indicate that significant differences in coefficients exist between Models 1 and 3 and Models 2 and 3. Gestational age in weeks is shown to give higher birth weights to infants in Model 3 compared to Models 1 and 2. Coefficients in Models 1 and 2 for gestational age in weeks are statistically different from the coefficient in Model 3, indicating that Model 3 overestimates the birth weight of infants based on gestational age. Statistically significant differences also exist between Models 1 and 3 and Models 2 and 3 for plurality status, maternal health complications during pregnancy, and abnormal health conditions of the infant at birth. Estimated coefficients and standard errors in

Model 3 for these variables indicate that infants weigh less if they are a twin, their mother has health complications during her pregnancy, or if the infant is born with an abnormal health condition.

Table 3.4: Individual Models of Birth Weight with and without Design Effects, Early Childhood Longitudinal Study – Birth Cohort; n=10,608

| | Model 1: Weighted with Design Effects [Coefficient (Standard Error)] | Model 2: Weighted without Design Effects [Coefficient (Standard Error)] | Model 3: Unweighted without Design Effects [Coefficient (Standard Error)] |
|---|---|---|---|
| **Biological Characteristics** | | | |
| Child Sex (1=male) | 124.16 (9.85)** | 124.16 (12.31)** | 120.92 (10.57)** |
| Gestational age (weeks) | 102.16 (3.20)** | 102.16 (2.97)** | 151.29 (1.56)** [a] |
| Twin (1=yes) | -649.18 (16.19)** | -649.18 (16.62)** | -405.31 (15.71)** [a] |
| Maternal Complications | -39.29 (15.22)* | -39.29 (14.18)* | -72.13 (11.54)** [b] |
| Newborn Conditions | -153.67 (29.65)** | -153.67 (29.18)** | -228.08 (17.62)** [c] |
| **Social Characteristics** | | | |
| Mom High School (ref=less than HS) | -15.25 (17.72) | -15.25 (18.92) | -2.94 (16.20) |
| Mom College or More | -17.42 (17.63) | -17.42 (20.44 | -19.14 (17.89) |
| Income | 0.0002 (0.0002) | 0.0002 (0.0002) | 0.0001 (0.0002) |
| Health Insurance (1=yes) | 36.73 (13.37)* | 36.73 (14.86)* | 11.96 (12.64) |
| Mother's Age at Birth | 28.42 (8.02)** | 28.42 (8.70)** | 25.98 (7.23)** |
| Mother's Age at Birth Squared | -0.37 (0.14)* | -0.37 (0.15)* | -0.33 (0.12)* |
| Black (reference=white) | -157.51 (18.80)** | -157.51 (18.63)** | -167.65 (16.82)** |
| Hispanic | -28.23 (18.88) | -28.23 (18.35) | -23.16 (16.19) |
| Asian | -193.18 (18.47)** | -193.18 (17.54)** | -104.87 (17.07)** [d] |
| Other | -86.36 (34.59)* | -86.36 (39.44)* | 1.54 (33.85) [b] |
| Married (1=yes) | 21.32 (16.77) | 21.33 (16.66) | 13.05 (14.60) |
| **Behavioral Characteristics** | | | |
| Smoke while Pregnant | -186.81 (19.04)** | -186.81 (21.23)** | -169.81 (18.14)** |
| Drink while Pregnant | -21.83 (70.53) | -21.83 (71.03) | 122.44 (65.69)† |
| Number Prenatal Visits | 4.79 (1.89)* | 4.79 (1.66)* | 2.36 (1.28)† |
| Weight Gain | 85.49 (7.79)** | 85.49 (7.94)** | 85.38 (6.69)** |
| Food Secure (1=yes) | 3.96 (21.32) | 3.96 (22.19) | 6.13 (18.09) |
| Pregnancy Not Wanted (ref=wanted preg) | 7.42 (24.47) | 7.42 (22.84) | 10.74 (18.65) |
| Pregnancy Not Sure | 36.99 (26.66) | 36.99 (24.66) | 68.25 (20.95)** |
| WIC (1=yes) | 10.03 (15.24) | 10.03 (16.02) | 4.87 (13.57) |
| **Intercept** | -1257.18 (173.91)** | -1257.18 (162.96)** | -3174.64 (115.72)** [a] |
| F | 410.40** | 305.18** | 731.53** |
| Pseudo $R^2$ | 0.3414 | 0.3414 | 0.6377 |
| N | 3899146 | 10608 | 10608 |

** p $\leq$.001 * p $\leq$.05 † $\leq$.10
a Coefficients for Model 1 and Model 3 and Model 2 and Model 3 are significantly different at p≤0.001
b Coefficients for Model 1 and Model 3 and Model 2 and Model 3 are significantly different at p≤0.1
c Coefficients for Model 1 and Model 3 and Model 2 and Model 3 are significantly different at p≤0.05
d Coefficients for Model 1 and Model 3 and Model 2 and Model 3 are significantly different at p≤0.01

Of the race/ethnicity variables in the model, significant differences are observed for Asian infants and infants of other or multiple races between Models 1 and 3 and Models 2 and 3. The coefficient for Asian infants in Model 3 suggests that Asian infants weigh less at birth than they do once the weighting and design effects are used to estimate the model. Further the relationship for infants of other or multiple races is statistically non-significant in Model 3, while Models 1 and 2 indicate that these infants weigh less at birth than white infants. The final significant difference between these models is in the intercept. Model 3 shows an intercept that is much lower than the intercept in Models 1 and 2.

In comparing these three models, it is important to note that Model 3 often overestimates relationships with birth weight or does not find statistically significant relationships that are observed when the models are weighted to the composition of the population of births and design effects are accounted for in the estimation techniques. Without careful estimation of models that take into consideration the sampling framework used in large, national data sets, results of analyses from these types of datasets should be read with caution. Results presented in Table 3.4 help to support this claim.

**Race-Specific Models of Birth Weight**

Results from the previous two tables indicate that statistically significant differences in birth weight outcomes exist based on race/ethnicity. In order to examine how the biological, social, and behavioral characteristics influence birth weights for individual racial groups, race-specific models are estimated. Due to the sampling design of racial and ethnic groups in the ECLS-B, jackknife estimation techniques are used to perform this analysis[4].

Table 3.5 presents results from the race-specific analysis for whites, blacks, Hispanics, Asians, and those of other or multiple races. Tests for differences across the racial/ethnic groups are also conducted in order to see if birth weights differ based on characteristics associated with a particular racial/ethnic group. Not much difference exists for gender between the races. Significant differences exist by race for other biological characteristics in the model. The coefficient for gestational age in weeks is significantly different for black infants and those infants of other or multiple races. Black infants tend to weigh more than infants of other or multiple races with each additional week of gestation. Twin infants of other and multiple races weigh significantly more at birth than white twin infants (364.95 grams less than a singleton birth compared to 687.41 grams less, respectively). Maternal health complications during pregnancy produce significantly lower birth weights for Asian infants compared to white infants.

Mothers of other or multiple races with a high school education have infants with significantly higher birth weights than infants of Hispanic mothers who have completed a high school education. Infants born to mothers of other or multiple races with a high school education have birth weights that differ significantly from Hispanic mothers with a high school education. Hispanic mothers with some college education or more have infants with significantly different birth weights than white mothers with some college

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[4] Jackknife estimation techniques are used for the group specific models, because many of the primary sampling units in the ECLS-B contain stratum based on the oversampling of certain individuals in the population. The Taylor Series method cannot accommodate this problem, so jackknife estimations are used instead. Both methods take into account the sample design in calculating standard errors.

education or more. Income is beneficial for the birth weights of Hispanic infants compared to whites and blacks.

Table 3.5: Individual Race-Specific Models of Birth Weight with Jackknife Estimation, Early Childhood Longitudinal Study – Birth Cohort, n=10,608

| | White | Black | Hispanic | Asian | Other Races |
|---|---|---|---|---|---|
| **Biological Characteristics** | | | | | |
| Child Sex (1=male) | 115.02** | 150.05** | 126.97** | 120.20** | 192.84* |
| Gestational age (weeks) | 101.93** | 113.02** | 95.30** | 97.39** | 82.21** [b] |
| Twin (1=yes) | -687.41** | -554.50** | -606.57** | -615.97** | -364.95* [w] |
| Maternal Complications | -21.70 | -45.51 | -91.90* | -98.90* [w] | 54.78 |
| Newborn Conditions | -116.90* | -236.94** | -255.85* | -131.54* | -83.78 |
| **Social Characteristics** | | | | | |
| Mom High School (ref=< HS) | 7.60 | -3.93 | -47.53 | -40.28 | 131.97† [h] |
| Mom College or More | 26.05 | -43.93 | -69.06† [w] | -60.14 | 57.69 |
| Income | 0.0001 | -0.0004 | 0.001* [w,b] | 0.0001 | -0.00003 |
| Health Insurance (1=yes) | 30.19† | 49.40 | 43.62 | -17.37 | 137.28 |
| Mother's Age at Birth | 21.70 | 18.74 | 31.15 | 41.76* | 112.37* |
| Mother's Age at Birth Squared | -0.27 | -0.19 | -0.42 | -0.56† | -2.07* [w, b] |
| Married (1=yes) | 27.78 | 45.44 | -2.15 | -51.26l | -54.57 |
| **Behavioral Characteristics** | | | | | |
| Smoke while Pregnant | -188.27** | -163.71* | -180.35† | 472.55* [w*,h*] | -102.57 [a] |
| Drink while Pregnant | -49.68 | 71.79 | 29.85 | -133.06 | -335.99 |
| Number Prenatal Visits | 8.49* | 5.01 | -1.66 [w] | 3.39 | 6.31 |
| Weight Gain | 90.39** | 100.69** | 66.71** | 74.95** | 114.73* |
| Food Secure (1=yes) | -4.63 | +13.07 | 15.54 | 70.67 | -43.58 |
| Pregnancy Not Wanted (ref=wanted) | 2.00 | 25.05 | -21.57 | -4.90 | -68.14 |
| Pregnancy Not Sure | 38.45 | 53.47 | 7.04 | -50.14 | 58.78 |
| WIC (1=yes) | 2.52 | 36.89 | 3.18 | 23.22 | -20.08 |
| Intercept | -1213.68 | -1735.96** | -967.75* | -1383.23* | -1696.18† |
| F | 283.43** | 83.09** | 47.06** | 45.25** | 22.88** |
| Pseudo $R^2$ | 0.3343 | 0.3928 | 0.2869 | 0.3117 | 0.3667 |
| N | 4734 | 1687 | 1812 | 1396 | 615 |
| Population of Births | 2275326 | 551886 | 911725 | 139060 | 92540 |

** p ≤.001 * p ≤.05 † ≤.10
w Coefficients for whites and Hispanics, whites and Asians, and whites and those of other or multiple races are significantly different at p≤0.05
w* Coefficients for whites and Asians are significantly different at p≤0.001
b Coefficients for blacks and Hispanics and blacks and those of other or multiple races are significantly different at p≤0.05
h Coefficients for Hispanics and those of other or multiple races are significantly different at p≤0.05
h* Coefficients for Hispanics and Asians are significantly different at p≤0.01
a Coefficients for Asians and those of other or multiple races are significantly different at p≤0.05

Higher levels of household income translate into higher birth weights for Hispanic infants, but income is not related to birth weight for white and black infants. Mother's age squared is significantly different for whites and those of other or multiple races and blacks and those of other or multiple races. While no significant difference exists just for the mother's age, of these three racial groups this variable is only significant for those of other or multiple races. Each additional year of age of the mother at the time of delivery leads to higher birth weights for infants of Asian and other or multiple races, but no significant association between maternal age at birth and birth weight exists for white, black, and Hispanic infants. However, as mothers of other and multiple races age past 30 those advantages decrease a great deal. No other significant differences exist for social characteristics across the racial groups.

A significant difference exists for the smoking behavior of mothers while pregnant for infant birth weights for whites and Asians and Hispanics and Asians. Both white and Hispanic mothers that smoke during pregnancy have infants with lower birth weights than Asian infants whose mother smoked during the pregnancy. The results shown in Table 3.5 also indicate that Asian mothers who smoke during pregnancy have infants weighing 472.55 grams more than infants born to Asian mothers who do not smoke. However, the direction of this relationship may reflect the small number of smokers among pregnant Asian women and Asian women in general, and this value should be interpreted with caution. A significant difference between Asian mothers who smoke during pregnancy and mothers of other or multiple races who smoke while pregnant is also observed. Of the remaining behavioral characteristics in the model, only the number of prenatal visits has a significant difference in determining birth weights for white and Hispanic infants.

Results from Table 3.5 indicate that not all biological, social, and behavioral mechanisms work the same for all racial groups in determining birth weights. For example, a white female, singleton infant that is born at 38 weeks of gestation, whose mother has a high school education, has a household income of $50,000, is 25 at the time of birth, attends 10 prenatal visits, and gains twenty-five pounds while pregnant would weigh 2,834.95 grams. For the same characteristics, a black infant would weigh 2,659.49 grams, a Hispanic infant would weigh 2,770.36 grams, an Asian infant would weigh 3,086.54 grams, and an infant of other or multiple races would weigh 3,190 grams.

**Sex-Specific Models of Birth Weight**

In each of the models presented above males weigh more at birth than females. Sex-specific models are estimated in order to explore differences in infant and maternal characteristics and their relationship with overall birth weight for male and female infants using Jackknife estimation techniques. Statistical tests are also used to test for differences in characteristics between male and female infants. Table 3.6 presents results from this analysis.

For all of the statistically significant relationships in these models, the directions of the relationships are the same. Gestational age in weeks is the only variable in the sex-specific models significantly different for males and females. For each additional week of gestation, males have higher birth weights than females. While no other statistically significant differences exist for the male and female models, it is interesting to note a few variables from the female models. Having health insurance has a significant positive relationship with birth weight for females, while this relationship is non-significant for males. Mothers that are married during pregnancy also have a significant positive relationship with birth weight for females but not for males.

Table 3.6: Individual Sex-Specific Models of Birth Weight with Jackknife Estimation, Early Childhood Longitudinal Study – Birth Cohort; n=10,608

| | Male | Female |
|---|---|---|
| **Biological Characteristics** | | |
| Gestational age (weeks) | 108.60** | 95.96** [a] |
| Twin (1=yes) | -662.11** | -634.64** |
| Maternal Complications | -44.99* | -35.24† |
| Newborn Conditions | -151.28** | -154.46** |
| **Social Characteristics** | | |
| Mom High School (ref=less than HS) | -33.95 | 0.29 |
| Mom College or More | -36.68 | 0.58 |
| Income | 0.0002 | 0.0001 |
| Health Insurance (1=yes) | 16.80 | 57.46* |
| Mother's Age at Birth | 25.72* | 32.18* |
| Mother's Age at Birth Squared | -0.33 | -0.43* |
| Black (reference=white) | -140.71** | -171.25** |
| Hispanic | -30.13 | -28.07 |
| Asian | -184.20** | -203.59** |
| Other | -34.25 | -131.73* |
| Married (1=yes) | 4.58 | 38.67† |
| **Behavioral Characteristics** | | |
| Smoke while Pregnant | -174.56** | -194.89** |
| Drink while Pregnant | 78.30 | -84.74 |
| Number Prenatal Visits | 6.91* | 2.40 |
| Weight Gain | 80.90** | 90.04** |
| Food Secure (1=yes) | 25.09 | -14.01 |
| Pregnancy Not Wanted (ref=wanted preg) | -17.38 | 31.70 |
| Pregnancy Not Sure | 8.94 | 62.17† |
| WIC (1=yes) | 3.20 | 18.84 |
| Intercept | -1345.16** | -1070.58** |
| F | 193.22** | 180.93** |
| $R^2$ | 0.3387 | 0.3362 |
| N | 5259 | 5037 |
| Population of Births | 2038124 | 1952691 |

** p ≤.001 * p ≤.05 † ≤.10

a Coefficients for male and female infants are significantly different at p≤0.05

A significant negative relationship exists for female infants of other or multiple races and birth weight that is not observed for male infants of this racial category. A marginally significant positive relationship is found for female infants if the mother is not sure about the wantedness of the pregnancy. Again no significant relationship for this variable and birth weight is observed for male infants. While previous research supports the finding that males tend to weigh more at birth than females, evidence to support this gender variation in these other relationships are not found in other research. Results from this study indicate that gender variation in birth weights may be attributable to differences in gestation.

**Plurality-Specific Models of Birth Weight**

Twins are often the focus of medical research, as they are seen as a natural control for biological, social, and behavioral characteristics that are common to the twins and their families. One consistent finding in infant health research is that twins are often born of different weights, leading the smaller infant of the pair to be more likely to experience infant mortality and twins in general tend to weigh less than singleton birth infants (Almond, Clay and Lee 2002). Results from the full model (Table 3.3, Model 5) in this analysis indicate that twins weigh 649.18 grams less on average than singleton infants. In order to examine why these differences exist between twins and singletons, twin-specific models were estimated. Statistical tests are conducted to see if significant differences exist between singleton and twin infants. Table 3.7 presents results from the twin-specific models using jackknife estimation techniques.

Several coefficients for variables in this model are found to be significantly different for singleton and twin infants. A significant difference exists between the sex of the infant and birth weight in this model. Each additional week of gestation leads to higher birth weights for twin infants compared to singleton infants. Maternal health complications during pregnancy only have a significant negative relationship for singleton infants, while abnormal health conditions of the infant at birth have a significant negative relationship with birth weight for both singleton and twin infants.

Table 3.7: Individual Plurality-Specific Models of Birth Weight with Jackknife Estimation, Early Childhood Longitudinal Study – Birth Cohort; n=10,608

| | Singletons | Twins |
|---|---|---|
| **Biological Characteristics** | | |
| Child sex (1=male) | 125.94** | 57.30* [a] |
| Gestational age (weeks) | 101.34** | 120.47** [a] |
| Maternal Complications | -40.49* | -17.21 |
| Newborn Conditions | -151.90** | -148.01** |
| **Social Characteristics** | | |
| Mom High School (ref=less than HS) | -17.41 | 61.03 |
| Mom College | -16.63 | -43.17 |
| Income | 0.0002 | -0.0007* |
| Health Insurance (1=yes) | 38.09* | -19.98 |
| Mother's Age at Birth | 28.72** | 19.25 |
| Mother's Age at Birth Squared | -0.38* | -0.19 |
| Black (reference=white) | -158.17** | -127.02* |
| Hispanic | -27.74 | -52.73 |
| Asian | -195.15** | -115.09* |
| Other | -91.54* | 156.25 [b] |
| Married (1=yes) | 20.95 | 45.98 |
| **Behavioral Characteristics** | | |
| Smoke while Pregnant | -187.80 | -166.75** |
| Drink while Pregnant | -33.73 | 238.06* [b] |
| Number Prenatal Visits | 4.85* | 4.02* |
| Weight Gain | 87.42** | 34.77* [c] |
| Food Secure (1=yes) | 3.07 | 44.49 |
| Pregnancy Not Wanted (ref=wanted preg) | 6.81 | 25.40 |
| Pregnancy Not Sure | 36.80 | 30.09 |
| WIC (1=yes) | 9.89 | 10.66 |
| Intercept | -1231.79** | -2357.82** [c] |
| F | 115.15** | 46.05** |
| $R^2$ | 0.2842 | 0.5063 |
| N | 8697 | 1599 |
| Population of Births | 3873413 | 117401 |

** p ≤.001 * p ≤.05 † ≤.10
a Coefficients for singleton and twin infants are significantly different at p≤0.01
b Coefficients for singleton and twin infants are significantly different at p≤0.05
c Coefficients for singleton and twin infants are significantly different at p≤0.001

Of all of the social characteristics included in the model, a significant difference is only found for singleton and twin infants' birth weight if they are of other or multiple races. Mothers who drink while pregnant and weight gain during pregnancy are the only two behavioral characteristics with significantly different coefficients for singleton and twin infants. Drinking while pregnant has a positive significant relationship with birth weight for twin infants. However, this coefficient should be interpreted with caution, because so few women consume alcohol while pregnant. Maternal weight gain during pregnancy is more beneficial to the birth weights of singleton compared to twin infants. The final significant difference between these two models is found for the intercept, and this difference is highly significant. Twin infants weight much less at birth on average than singleton infants. This result supports findings from other research examining birth weight differences for singleton and twin infants. For all of the other relationships in Table 3.7, no statistically significant differences exist between singleton and twin infants.

Each of the models presented to this point have examined the relationships between biological, social, and behavioral characteristics and how they influence individual birth weights in grams. Some consistent findings to emerge across all of the models are that gestational age has a positive relationship with birth weight, while being a twin lowers birth weight. In all of the models, black and Asian infants tend to weigh less at birth than white infants. Smoking has a strong negative relationship with birth weight. While these models offer insight into how various infant and maternal characteristics affect birth weights, they do not offer explanations into which factors are more or less likely to lead to an infant being born with low birth weight. The next section of this chapter displays results from logistic regression models that estimate the relationships of these biological, social, and behavioral characteristics on the odds of an infant being born of low birth weight status.

**The Impact of Biological, Social, and Behavioral Characteristics on Low Birth Weight Status**

This section of this chapter examines the impact of biological, social, and behavioral measures on the odds of low birth weight status of individual infants. Low birth weight is operationalized as a dichotomous dependent variable. An infant is considered to be low birth weight if the infant weighs less than 2,500 grams, or 5.5 pounds. All other infants are considered of normal birth weight. In the ECLS-B, both moderately low and extremely low birth weight infants are oversampled, but these two categorizations of low birth weight are combined as a single indicator of low birth weight status. Proper estimation techniques are used to account for the sample design used in the ECLS-B. Logistic regression is used in this set of analyses in order to accommodate the use of the dichotomous dependent variable. As presented in Table 3.1, 92.6 percent of the infants in the weighted sample are normal birth weight, leaving 7.4 percent of infants as low birth weight.

Table 3.8 presents the results of nested models using biological, social, and behavioral characteristics of infants and mothers to determine the odds of an infant being born low birth weight. Biological measures are added in the first model. The subsequent models add socioeconomic characteristics of the mother, then mother's age, race/ethnicity, and marital status to round out the social characteristics. Finally smoking behavior during pregnancy is added to the previous models, and then the remaining behavioral characteristics are added in the full model. The models are estimated using Taylor series methods to estimate standard errors. Odds ratios for each of the variables are listed in the table.

Table 3.8: Logistic Regression Individual-Level Models of Low Birth Weight Status with Design Effects, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Odds Ratio (Standard Error)

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|
| **Biological Characteristics** | | | | | |
| Child Sex (1=male) | 0.76 (0.06)** | 0.76 (0.06)** | 0.76 (0.06)** | 0.76 (0.06)** | 0.77 (0.06)* |
| Gestational age (weeks) | 0.58 (0.01)** | 0.59 (0.01)** | 0.59 (0.01)** | 0.59 (0.01)** | 0.59 (0.01)** |
| Twin (1=yes) | 7.47 (0.57)** | 8.09 (0.59)** | 8.56 (0.66)** | 8.73 (0.69)** | 10.36 (0.83)** |
| Maternal Complications | 1.76 (0.41)** | 1.77 (0.14)** | 1.74 (0.14)** | 1.69 (0.14)** | 1.72 (0.14)** |
| Newborn Conditions | 2.12 (0.32)** | 2.15 (0.32)** | 2.22 (0.32)** | 2.24 (0.33)** | 2.30 (0.35)** |
| **Social Characteristics** | | | | | |
| *Socioeconomic Status* | | | | | |
| Mom High School (ref=less than HS) | | 1.04 (0.12) | 1.11 (0.13) | 1.17 (0.13) | 1.21 (0.14) |
| Mom College or More | | 0.85 (0.09) | 0.96 (0.11) | 1.08 (0.13) | 1.13 (0.15) |
| Income | | 1.00 (0.000001)* | 1.00 (0.000001)* | 1.00 (0.000001) | 1.00 (0.000001) |
| Health Insurance (1=yes) | | 0.89 (0.07) | 1.04 (0.09) | 1.06 (0.09) | 1.04 (0.09) |
| *Sociodemographics* | | | | | |
| Mother's Age at Birth | | | 0.85 (0.04)* | 0.84 (0.04)** | 0.83 (0.04)** |
| Mother's Age at Birth Squared | | | 1.00 (0.001)** | 1.00 (0.001)** | 1.00 (0.001)** |
| Black (reference=white) | | | 1.58 (0.17)** | 1.79 (0.20)** | 1.73 (0.19)** |
| Hispanic | | | 1.06 (0.09) | 1.25 (0.11)* | 1.19 (0.12)† |
| Asian | | | 1.54 (0.18)** | 1.71 (0.21)** | 1.54 (0.20)** |
| Other | | | 1.39 (0.35) | 1.35 (0.35) | 1.26 (0.35) |
| Married (1=yes) | | | 0.74 (0.08)* | 0.78 (0.08)* | 0.75 (0.08)** |
| **Behavioral Characteristics** | | | | | |
| Smoke while Pregnant | | | | 1.94 (0.25)** | 2.09 (0.27)** |
| Drink while Pregnant | | | | | 1.62 (0.76) |
| Number Prenatal Visits | | | | | 1.00 (0.01) |
| Weight Gain | | | | | 0.68 (0.04)** |
| Food Secure (1=yes) | | | | | 1.12 (0.19) |
| Pregnancy Not Wanted (ref=wanted preg) | | | | | 1.15 (0.18) |
| Pregnancy Not Sure | | | | | 0.90 (0.17) |
| WIC (1=yes) | | | | | 0.82 (0.08)† |
| F | 616.68** | 394.66** | 210.67** | 190.11** | 145.40** |

** p ≤.001 * p ≤.05 † ≤.10

Model 1 in Table 3.8 explores the relationships between biological characteristics and the chances of being born low birth weight. For males, the odds of being born low birth weight is three-fourths that of female infants. The odds of being born low birth weight is less than half as likely with each additional week of gestation. Twins are 7.47 times more likely to be born low birth weight than singleton infants. As is expected, mothers experiencing medical complications during the pregnancy are 1.76 times more likely to have a low birth weight infant as mothers not having medical complications. Infants with abnormal health conditions at birth are 2.12 times more likely to be born low birth weight than infants not experiencing abnormal health conditions at birth.

Measures of socioeconomic status of the mother are added in Model 2 in Table 3.8. Mother's educational levels and insurance status are not statistically significant in predicting odds of low birth weight status of infants. The odds ratio for household income is statistically significant. Mother's age at birth, mother's age at birth squared, race/ethnicity, and marital status are incorporated into Model 3 in Table 3.8. Black (1.58) and Asian (1.54) infants are more likely to be born low birth weight than white infants. Each additional year of age of the mother at the time of delivering her infant decreases her chances of having a low birth weight infant. The odds ratio for the squared term for mother's age during pregnancy is 1.00. Marriage is protective against having a low birth weight infant in that the odds of having a low birth weight infant for married mothers is three-fourths that of infants born to unmarried mothers. The odds that twins will be born low birth weight increases (8.56) with the inclusion of all biological and social characteristics in Model 3. Income remains significant in determining the likelihood that the infant will be low birth weight once all social variables are added in this model.

Model 4 in Table 3.8 incorporates smoking behaviors of the mother while pregnant. Infants born to mothers that smoke during pregnancy are 1.94 times more likely to be born low birth weight. All other odds ratios are similar with this addition, except Hispanic infants become 1.25 times more likely to be born low birth weight compared to white infants when smoking behavior is included in this model. Also income is no longer statistically significant in this model. The remaining behavioral characteristics are added in Model 5. A mother who gains more than twenty-five pounds during pregnancy is much less likely to have an infant born low birth weight compared to women gaining less than twenty-five pounds. Specifically, a mother that gains between twenty-five and thirty-four pounds during her pregnancy is a little more than two-thirds as likely as mothers gaining less than twenty-five pounds to have a low birth weight baby. WIC usage is also found to lower the odds that an infant will be born low birth weight compared to women not using the program during her pregnancy. Other significant relationships in Model 4 remain with the inclusion of all variables in the full model.

Similar to the models presented above, smoking during pregnancy is an important behavioral characteristic in determining not only individual birth weight in grams, but, as evidenced in Model 5 of Table 3.8, one of the most important factors in determining the low birth weight status of infants. It is also interesting to note that WIC is protective against low birth weight status for women that take advantage of the supplemental program while pregnant. This finding could have important implications for health policies targeting birth weight and poverty. Further, black, Hispanic, and Asian mothers have odds that are much higher for having a low birth weight infant compared to white mothers when all variables are included in the full model. Although eliminating smoking behaviors among racial groups may not eradicate the racial differences in determining the low birth weight status of infants, it may help to narrow the gap. While many biological conditions cannot be prevented or controlled, education about the risks of smoking during pregnancy may help to reduce the risk of low birth weight status for certain individuals in the population. The following section looks at differences based on race/ethnicity more closely in order to better understand how biological, social, and behavioral characteristics operate differently to influence low birth weight status.

**Race-Specific Models of the Odds of Low Birth Weight**

Results from the previous table (Table 3.8) indicate that the likelihood of being born low birth weight differs based on the infant's race/ethnicity. This section examines how measures in the previous models operate differently for various racial and ethnic groups in determining the odds that an infant will be born low birth weight. Tests for differences are also conducted to see if relationships for predicting low birth weight status vary based on race/ethnicity.

Table 3.9 presents results from five race-specific models using Jackknife estimation techniques to account for the primary sampling unit design in the ECLS-B. Significant differences do exist in the odds of low birth weight status of an infant based on the infant's race/ethnicity. Black and Asian male infants have significantly different odds of being low birth weight than white male infants. Of the remaining biological characteristics, a significant difference exists between white mothers having

Table 3.9: Logistic Regression Individual-Level Race-Specific Models of Low Birth Weight Status with Jackknife Estimation, Early Childhood Longitudinal Study – Birth Cohort; n=10,608,
Odds Ratio (Jackknife Standard Error)

| | White | Black | Hispanic | Asian | Other Races |
|---|---|---|---|---|---|
| **Biological Characteristics** | | | | | |
| Child Sex (1=male) | 0.94 (0.11) | 0.48 (0.08)** [w] | 0.81 (0.17) | 0.54 (0.13)* [w] | 0.37 (0.21)† |
| Gestational age (weeks) | 0.58 (0.02)** | 0.63 (0.03)** | 0.56 (0.03)** | 0.55 (0.05)** | 0.69 (0.13)† |
| Twin (1=yes) | 11.19 (0.145)** | 10.71 (2.34)** | 10.63 (2.39)** | 10.17 (4.24)** | 4.79 (7.21) |
| Maternal Complications | 1.92 (0.23)** | 1.70 (0.29)* | 1.82 (0.35)* | 1.53 (0.49) | 0.35 (0.29) [w] |
| Newborn Conditions | 1.85 (0.36)* | 3.02 (1.13)* | 3.40 (1.24)** | 2.43 (1.02)* | 4.05 (2.99)† |
| **Social Characteristics** | | | | | |
| Mom High School (ref=< HS) | 1.11 (0.28) | 0.78 (0.19) | 1.91 (0.48)* | 0.50 (0.28) [h] | 0.89 (0.70) |
| Mom College or More | 0.83 (0.24) | 1.35 (0.39) | 1.33 (0.38) | 0.82 (0.40) | 0.43 (0.53) |
| Income | 1.00 (0.000001) | 1.00 (0.000003) | 1.00 (0.000005)† [b] | 1.00 (0.000004) | 1.00 (0.00001) |
| Health Insurance (1=yes) | 1.13 (0.11) | 0.98 (0.22) | 1.00 (0.24) | 0.65 (0.21) | 0.36 (0.24) |
| Mother's Age at Birth | 0.8. (0.07)* | 0.95 (0.09) | 0.82 (0.10)† | 0.78 (0.15) | 0.41 (0.16)* [b] |
| Mother's Age at Birth Squared | 1.00 (0.001)* | 1.00 (0.002) | 1.00 (0.002)† | 1.00 (0.003) | 1.02 (0.01)* [b] |
| Married (1=yes) | 0.72 (0.13)† | 0.71 (0.14)† | 0.79 (0.19) | 3.55 (1.59)* [w*,b*,h] | 3.60 (2.63)† [w,b,h] |
| **Behavioral Characteristics** | | | | | |
| Smoke while Pregnant | 1.83 (0.33)** | 1.81 (0.51)* | 5.77 (2.67)** [b] | -- [w*,h] | 1.41 (0.92) |
| Drink while Pregnant | 2.10 (1.36) | 0.88 (0.84) | 1.45 (0.93) | -- | 1.21 (1.78) |
| Number Prenatal Visits | 0.98 (0.02) | 1.01 (0.02) | 1.03 (0.02)† | 0.97 (0.04) | 1.08 (0.14) |
| Weight Gain | 0.73 (0.05)** | 0.62 (0.08)** | 0.57 (0.08)** | 0.70 (0.10)* | 0.54 (0.21) |
| Food Secure (1=yes) | 1.06 (0.32) | 0.96 (0.25) | 1.24 (0.45) | 1.00 (0.56) | 0.75 (0.70) |
| Pregnancy Not Wanted (ref=wanted) | 1.11 (0.34) | 1.14 (0.27) | 1.61 (0.57) | 2.92 (1.43)* | 0.49 (0.46) |
| Pregnancy Not Sure | 0.77 (0.33) | 1.35 (0.36) | 0.51 (0.21)† [b] | 1.64 (0.97) | 1.26 (0.94) |
| WIC (1=yes) | 0.76 (0.12)† | 0.64 (0.14)* | 0.93 (0.23) | 0.72 (0.26) | 1.65 (1.22) |
| F | 77.35** | 36.61** | 26.38** | 9.81** | 4.38** |
| N | 4817 | 1687 | 1812 | 1396 | 615 |
| Population of Births | 2275326 | 551886 | 911725 | 139060 | 92540 |

** p ≤.001 * p ≤.05 † ≤.10 -- Smoke and drink predicts failure perfectly in Asian specific model
w Coefficients for whites and blacks, whites and Asians, and whites and those of other or multiple races are significantly different at p≤0.05
w* Coefficients for whites and Asians are significantly different at p≤0.001
b Coefficients for blacks and Hispanics and blacks and those of other or multiple races are significantly different at p≤0.05
b* Coefficients for blacks and Asians are significantly different at p≤0.001
h Coefficients for Hispanics and Asians and Hispanics and those of other or multiple races are significantly different at p≤0.05

complications during pregnancy and mothers of other or multiple races having medical complications. White mothers experiencing health complications during pregnancy are 1.92 times more likely to have a low birth weight infant than white mothers having no medical complications during pregnancy. The odds ratio for mothers of other or multiple races for this same variables indicates that the odds of having a low birth weight infant are lower if the mother has a medical complication while pregnant.

Hispanic and Asian mothers completing a high school education have significantly different odds ratios for having a low birth weight infant. Asian mothers with a high school education are half as likely to have a low birth weight infant compared to Asian mothers with less than a high school education. Hispanic mothers completing a high school education are more likely than Hispanic mothers without a high school education to have a low birth weight infant. A significantly different relationship exists between household income and the odds of low birth weight between black and Hispanic infants. Of the remaining social characteristics included in Table 3.9, a significant difference is found between marital status and the odds of low birth weight status for whites and Asians, blacks and Asians, Hispanics and Asians, whites and those of other races, blacks and those of other races, and Hispanics and other races. For whites, blacks, and Hispanics, being married at the time of pregnancy decreases the odds that an infant will be low birth weight. One the other hand, Asian mothers and mothers of other or multiple races have odds ratios for marital status that indicate that being married while pregnant increases the odds that an infant will be low birth weight.

The relationship between smoking behavior and the odds of low birth weight is found to differ significantly for blacks and Hispanics, as well as for whites and Asians and Hispanics and Asians. Differences based on pregnancy wantedness, particularly the mother not being sure if she wants the pregnancy, are significantly different for blacks and Hispanics. The sign of the coefficient for this variable differs for these two racial groups. While no significant difference is found for WIC use, a statistically significant relationship for WIC usage is present for whites and blacks indicating that WIC use is protective against low birth weight.

Results from the race-specific logistic models presented above raise some interesting points about the study of low birth weight. While most of the biological variables included in these models have similar results for each racial group, social and behavioral characteristics for the racial/ethnic groups lead to very different relationships with low birth weight. Some measures may be protective for some races while other measures are detrimental. Income offers an advantage to Hispanics by decreasing the likelihood that Hispanic infants will be born low birth weight with each additional level of income. However, Hispanics have the highest odds ratio of any of the racial groups for having a low birth weight infant if the mother smokes during pregnancy. One finding that has only been significant in the race-specific logistic models is the decrease in the likelihood that a white mother or a black mother will have a low birth weight infant if she uses WIC during her pregnancy. Still white and black women with low incomes using this program have a better chance of having a normal weight infant than low income white and black mothers not using the program. Wantedness of the pregnancy also becomes important for Hispanics and Asians in these models, a relationship which had not been observed in any of the previous models. The variation across these models leads to more complexity when trying to suggest policy recommendations to help prevent the occurrence of low birth weight when many of the relationships between variables in the models and low birth weight status are socially and behaviorally associated with specific racial groups. Therefore policy may need to be targeted to different groups.

## Discussion

This chapter explored the statistical relationships between biological, social, and behavioral characteristics of infants and mothers and individual birth weight in grams and odds of low birth weight status. The first set of analyses examined these relationships as they were associated with variation in birth weights. The second set of analyses considered these relationships as they increase or decrease the likelihood of an infant being born low birth weight.

Similar to clinical and individual level studies of birth weight, results in this chapter indicate that biological characteristics of the mother and infant are most important in determining birth weights. These include measures of gestational age, plurality status, maternal health complications during pregnancy, and abnormal health conditions of the infant at birth. Smoking behavior while pregnant was the most important behavioral characteristic of the mother to emerge in determining overall birth weights and the low birth weight status of infants.

While the health and inequality literature shows a strong relationship between socioeconomic status and health outcomes, results from the full models in this chapter do not support this finding. When maternal educational levels and household income are first introduced in the models, they do have a significant positive relationship with higher birth weight and lower the likelihood that an infant will be born low birth weight.

However, the addition of family characteristics and maternal behaviors during pregnancy mediate this relationship in the full sample. Race-specific models indicate that higher socioeconomic status is advantageous for Hispanic infants.

Results from the race-specific models also provide detail into how the biological, social, and behavioral variables included in these models vary for different racial and ethnic groups. Based on results in this chapter, future research in health inequalities should focus more on biological and behavioral differences based on race/ethnicity if differences in birth weights are to be eliminated. Further, the use of WIC by low income white and black women is protective against having a low birth weight infant, so policies should be geared towards reaching all low income women to help eliminate some of the racial gap in low birth weight.

In looking at results from this chapter, two questions remain. First, have birth weights in the United States increased in the past two to three decades such that another standard for measuring low birth weight infants needs to be devised? Second, should a race-specific standard be used in measuring low birth weight since certain racial groups tend to have women that are physically smaller or larger at the time they conceive? These two questions should be central in the debate about variation in infant and maternal health outcomes. Similarly, studies focusing on infants weighing too much at birth, whatever that weight range may be, should also be explored for possible negative health outcomes. Looking beyond individual-level predictors of birth weights also adds to the policy relevance of this topic, and the use of multilevel methods is employed in the next chapter to better situate health differentials from a structural perspective.

# Chapter 4

# Rurality, Income Inequality, and Contextual Effects: Implications for Birth Weight Using Multilevel Methods

## Introduction

Two traditional paradigms have largely framed health research. These include individual risk and behavioral epidemiology and an ecological approach (Pickett and Pearl 2001). Both types of models have found consistent results, especially with relationships examining health status and socioeconomic status at the individual level and income inequality at the contextual level. However neither approach fully accounts for all variation in health outcomes. Further the health conditions of individuals are not solely determined by biological and behavioral mechanisms but are also influenced by the spatial locations in which individuals live and interact. Ecological factors have been argued to be the most crucial determinants of the health status of a population (Winkelstein 1972). Macintrye and colleagues (1993) argue that the neighborhoods in which individuals live may influence health through mechanisms such as availability and access of health care services, infrastructure deprivation, the prevalence of attitudes towards health and health related behaviors, and stress and lack of social support.

Differences in residential locations have also been found to lead to differences in health and mortality outcomes. Research focusing on health outcomes for rural and urban residents finds that nonmetropolitan residents tend to have lower mortality rates than their metropolitan counterparts (McLaughlin, Stokes and Nonoyama 2001).

Research also indicates that variation in adult mortality and morbidity patterns exist based on the degree of rurality for a particular county, with specific reference to the county's population size and adjacency to a metropolitan area (Morton 2004). Placing individuals within a multilevel framework allows better estimation of health differentials by capturing not only individual variation in the outcome of interest but also acknowledging the importance contextual-level variables have by locating individuals within the places they live for determining individual health outcomes.

In this chapter, I use multilevel modeling techniques to explore the impact of contextual-level measures on individual birth weights and the odds of low birth weight status of infants. Particular attention is given to the level of rurality for an infant's county of residence at the contextual level in order to examine residential variation in birth weights for rural residents. Individual-level variables described in Chapter 3 are combined in this analysis with county-level socioeconomic, sociodemographic, social capital, and health care measures in order to estimate two-level random intercept multilevel models. Estimation of these models allows for a better understanding of how birth weights and the odds of low birth weight status are influenced by not only individual biological, social, and behavioral characteristics but also by the social context of an individual's residential location.

## Data and Methods

Individual-level data are taken from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B). An explanation of the sample and sampling design of the ECLS-B is found in the data and methods section of Chapter 3. Variables at the individual-level include the sex of the infant, gestational age, plurality status of the birth, maternal weight gain during pregnancy, maternal health complications during pregnancy, abnormal health conditions of the infant at birth, mother's educational level and household income, mother's age at birth and mother's age squared, race/ethnicity of the infant, mother's marital status, health insurance status, number of prenatal visits, smoking and alcohol consumption while pregnant, food security status of the household, wantedness of the pregnancy, and the use of WIC during the pregancy. For one set of analyses in this chapter the outcome variable is individual birth weight in grams, a continuous measure. The second set of analyses uses a dichotomous dependent variable for whether an infant is born low birth weight or not. Further descriptions of variables used at level-I (individual-level) and the dependent variables are also detailed in Chapter 3.

The ECLS-B contains two variables that provide geographical identifiers for infants in the sample, two-digit state codes and three-digit county codes for the infant's county of residence. These two variables are combined to create five-digit federal information processing standards codes (fips codes). Fips codes are a standardized set of numeric codes released by the National Institute of Standards and Technology (NIST) to provide standardized identification of geographic units, in this case counties (U.S. Census Bureau 2001). Fips codes from the ECLS-B were then merged with secondary data sources aggregated to the county-level to provide socioeconomic, residential, social capital, social environment, and health services measures to be used as level-II variables for this multilevel analysis. Specific county-level data sources and variables are detailed below. The state and county codes provided in the ECLS-B are part of the restricted data file. State and county codes were available for all infants in the sample except for eighty individuals. These eighty cases were eliminated from the final sample in this analysis, because no geographical identifiers were available for these cases to be merged with other county-level variables.

**Secondary Data Sources and Measures**

A variety of secondary data sources were used to construct variables at the county-level for this analysis. These sources include Economic Research Service Rural-Urban Continuum Codes; 2000 U.S. Census of Population and Housing, Summary File 3 (SF3); 2000 County Business Patterns; 2000 Uniform Crime Reports; and the 2004 Area Resource Files. Descriptions of these data sets and variables used from them are given below arranged by the five sets of characteristics at the structural-level found to influence individual infant health outcomes. These include residential, socioeconomic, social capital, social environment, and health services characteristics.

**Rural-urban continuum codes** were selected for this analysis in order to capture variation in the outcome based on the degree of rurality for the infant's county of residence and constitute one of the measures of residential characteristics at the structural-level. The Economic Research Service provides the codes for each of the 3,141 counties in the United States. The codes create a classification system that differentiates metropolitan counties by the population size of the metro area, and nonmetropolitan counties by their degree of urbanization and adjacency to a metropolitan area or areas (Economic Research Service 2004). Within this classification scheme, four codes represent metro counties and six codes represent nonmetro counties and these codes represent one of the measures of rurality in this analysis[5]. Since births in the ECLS-B were sampled from all births occurring in the calendar year 2001, 1993 rural-urban continuum code classifications are used in this analysis since more recent rural-urban continuum codes are based on 2003 designations. This county classification scheme was selected for this analysis due to the concept of adjacency incorporated into the codes. The concept of adjacency is important when examining differences in rural health outcomes, because this concept provides important insight into underlying economic and social characteristics of counties (Morton 2004). Specifically, adjacency in a spatial context represents the commuting patterns for employment, income distributions, and the transfer of goods and services across space. Adjacency is also important when looking at utilization and access to health care, food, education, and social services.

A dichotomous measure of **metro/nonmetro county status** is also constructed from this coding scheme to represent another measure of residential characteristics, in which codes 0 through 3 represent metro counties (coded 1) and codes 4 through 9 represent nonmetro counties (coded 0). Two other measures of rurality are used in this analysis. These include the percentage of the **county population that is rural** and county **population density**. These two measures are taken from the 2000 US Census of Population and Housing, Summary File 3. The percentage of the county population that is rural, defined as a population not classified as urban by the Census Bureau, is

[5] County classifications based on the 1993 rural-urban continuum codes are as follows: (0) Central counties of metro areas of 1 million population or more; (1) Fringe counties of metro areas of 1 million population or more; (2) Counties in metro areas of 250,000 to 1 million population; (3) Counties in metro areas of fewer than 250,000 population; (4) Urban population of 20,000 or more, adjacent to a metro area;(5) Urban population of 20,000 or more, not adjacent to a metro area; (6) Urban population of 2,500 to 19,999, adjacent to a metro area; (7) Urban population of 2,500 to 19,999, not adjacent to a metro area; (8) Completely rural or less than 2,500 urban population, adjacent to a metro area; (9) Completely rural or less than 2,500 urban population, not adjacent to a metro area.

constructed by dividing the county's rural population by the total population and multiplying this value by 100. Population density is measured as the county population divided by the county land area in square kilometers. Models using these three measures of rurality (rural-urban continuum codes; metro/nonmetro county status; and the percentage of the county population that is rural and population density for the county) are estimated to test for variation in birth weight across different types of places.

County-level economic and sociodemographic characteristics are taken from the 2000 U.S. Census of Population and Housing, Summary File 3. One key indicator of income inequality that is commonly used due to its ease of interpretation is the **Gini coefficient**. The Gini coefficient ranges from 0, indicating complete equality of incomes, to 1, which represents complete inequality of incomes. This measure of income inequality specifies the degree to which the income distribution among households differs from an equal distribution of income (Allison 1978). Other measures of inequality used in health literature include the Robin Hood Index, Atkinson's index, Theil's entropy measure, and income share distributions. However, the choice of inequality measure makes little difference in the health and inequality research (Beckfield 2004). Two key variables from the 2000 Census include county level measures of racial composition. Specifically, the racial composition variables consist of the percentage of residents in the county who are black and the percentage of county residents who are Hispanic. These two variables constitute the county **percent black** and **percent Hispanic** measures.

Three other variables taken from the Census include the median household income for each county, the percentage of unemployed residents in the county, and the percentage of the county population over the age of twenty-five that has completed a college education. Violent crime rates and property crime rates were constructed from the county-level file in the 2000 Uniform Crime Reports, which include detailed arrest and offense information at the county-level, for each county in the analysis. Violent crimes consist of murder, rape, robberies, and aggravated assaults. Burglaries, larcenies, motor vehicle thefts, and arsons constitute property crimes found in the Uniform Crime Reports. The total number of crimes in each of the two categories for the county is calculated per 10,000 residents. The health service personnel variables listed above were taken from the Area Resource Files (ARF), collected by the Bureau of Health Professions for the Health Resources and Services Administration. The 2004 release of the data is used because they contain the total number of health facilities and professionals from 2000 and correspond with population counts from the other secondary data sources used for this analysis.

Preliminary tests for multicollinearity (not shown here) indicate that these variables were highly correlated. Factor analysis was used to reduce the total number of variables used at level-II of this analysis and to prevent multicollinearity. These include the median household income for each county, the percentage of unemployed residents in the county, the percentage of the county population over the age of twenty-five that has completed a college education, socioeconomic characteristics; the violent crime rate and property crime rate for the county, both social environment characteristics; and the total number of medical doctors (MD's), pediatricians, obstetricians/gynecologists, and emergency medical personnel per 10,000 residents in the county, health services characteristics.

Results from the factor analysis using the variables described above are found in Table 4.1. The mean and standard deviations for each of the variables is presented and then the factor scores using principal axis factoring and promax (oblique) rotation, which produced the most simple factor structure, are detailed. Three factors emerged with the inclusion of these variables, and the factor loadings for each of the three factors are very high with the lowest loading having a value of -0.760. First is a health services factor that includes the total number of medical doctors (MD's), total number of pediatricians, total number of obstetricians/gynecologists, and total emergency medical personnel each per 10,000 population for the county. This factor has an eigenvalue of 4.070 and explains 45.22 percent of the variance.

Table 4.1: Descriptive Statistics, Factor Loadings, Eigenvalues, and Explained Variance of Factor Solution for County-Level Measures

| Observed Variables | Mean | Standard Deviation | Factor Scores: (1) Health Services | (2) Economic | (3) Crime |
|---|---|---|---|---|---|
| Percent Pop 25+ with College Ed | 27.28 | 9.53 | 0.582 | 0.834 | -0.134 |
| Percent Unemployed | 6.07 | 2.11 | -0.142 | -0.760 | 0.467 |
| Median Household Income | 43930.22 | 10894.17 | 0.133 | 0.904 | -0.174 |
| Violent Crime Rate/10,000 pop | 23.09 | 16.15 | 0.149 | -0.313 | 0.845 |
| Property Crime Rate/10,000 pop | 58.55 | 30.19 | -0.038 | -0.178 | 0.805 |
| Total MDs/10,000 pop | 33.30 | 24.89 | 0.971 | 0.210 | 0.030 |
| Total Pediatricians/10,000 pop | 2.22 | 1.50 | 0.964 | 0.298 | 0.063 |
| Total OB-GYNs/10,000 pop | 1.55 | 0.82 | 0.926 | 0.300 | 0.176 |
| Total Emergency Medical Personnel/10,000 pop | 0.98 | 0.64 | 0.893 | 0.231 | 0.018 |
| Eigenvalue | | | 4.070 | 2.161 | 1.045 |
| % of Variance Explained | | | 45.222 | 24.012 | 11.607 |
| Cumulative % Explained | | | 45.222 | 69.234 | 80.841 |

Extraction Method: Principal Axis Factoring
Rotation Method: Promax (Oblique) Rotation

The second factor captures economic measures of the county and consists of the percentage of the county population aged 25 and over with a college education, the percentage of the county population unemployed, and the median household income for the county. Factor 2 has an eigenvalue of 2.161 and explains 24.01 percent of the variance in the factor. The remaining two variables (the violent and property crime rates for the county) make up the third factor, a measure of the social environment. This measure explains 11.61 percent of the variation in the third factor. Therefore the three factors to emerge from this factor analysis are made into factor scores included as measures at level-II for the multilevel models making a **health services factor**, an **economic factor**, and a **crime factor**.

Social capital variables, including Putnam- and Olsen-type establishments, were constructed from information in the 2000 County Business Patterns dataset. Rupasingha, Goetz, and Freshwater (2000) developed two measures of social capital based on the associational activities in counties[6]. **Putnam-type establishments** consist of the total number of bowling centers, public golf courses, membership sports and recreation clubs, civic and social associations, and religious organizations in the county. **Olsen-type establishments** are more business related and include labor organizations, business associations, professional organizations, and political organizations found in each county. The construction of both of these variables is based on the total number of establishments in each category within the county per 10,000 persons in 2000.

One remaining level-II variable is taken from the Area Resource Files. This is the **total number of hospitals** in each county and is calculated as a rate per 10,000 population. This variable was included in the factor analysis above, but this variable did not load on any of the three factors, so it was kept as a separate measure and captures

[6] Original classifications of establishment types used in the work of Rupasingha, Goetz, and Freshwater (2000) were based on the 1997 U.S. Standard Industrial Classification (SIC) system and County Business Patterns data for 1990. In order to construct Putnam and Olsen variables for 2000, the North American Industry Classification System (NAICS) was matched to pervious SIC codes for the same type of establishments to ensure comparability of the variables for the two different time periods.

another dimension of the health service characteristics of the county. Taken together these county-level measures represent the residential, socioeconomic, social capital, social environment, and health services characteristics used at level-II of this multilevel analysis. Methods of multilevel analysis are detailed below.

**Multilevel Methods**

The two levels of analysis in this research were selected to take into account the impact of socioeconomic status and inequality on birth weight as well as considering other individual- and structural-level covariates. In this analysis, individual biological, social, and behavioral characteristics of infants and their families constitute the level-I, or individual-level, variables and serve as controls in the models. The level-II, or contextual, variables include residential, socioeconomic, social capital, social environment, and health services measures. Much debate exists about the proper level of aggregation to use to look at the impact of inequality on health outcomes. However, counties provide a good structure to understand how decisions about planning and development are made, as well as how structures within smaller governmental units operate (Lobao 1990; Lobao and Hooks 2003). Counties were selected over states, because they can offer more insight into the variation that exists in inequality across space and great variation in local conditions within states exists. Smaller units, such as blocks or census tracts, may not capture this variation. Further, counties were selected as the level of aggregation so that the influence of multiple levels of rurality on birth weight can be ascertained.

The combination of the ECLS-B, Economic Research Service rural-urban continuum codes, 2000 U.S. Census of Population and Housing Summary File 3, 2000 County Business Patterns, 2000 Uniform Crime Reports, and 2004 Area Resource Files allows the opportunity to analyze individual birth weights and the odds of low birth weight status in a multilevel framework to account for the clustering of infants within counties. A total of 10,608 infants are clustered in 176 counties. Since county identifiers are a part of the restricted data file, specific counties used in this analysis cannot be identified. Some counties had to be combined due to the sampling design of the ECLS-B and the small number of cases within individual counties (see Appendix B for a full description of the county combining procedure).

Due to the clustering of infants within counties, a more common method of analysis, such as ordinary least squares (OLS) regression, would not be appropriate. OLS regression assumes independence among observations and normally distributed random errors. The clustered nature of the data in this analysis violates these assumptions. Observations within clusters tend to be more similar than observations chosen randomly, making the errors within these clusters correlated. Without taking into consideration the clustering of infants within counties in this analysis, standard errors will be biased downward and statistical significance will be overestimated.

With the inclusion of individual- and county-level measures, hierarchical linear modeling, using HLM 6 and STATA 9, will provide more robust standard errors and unbiased estimates of the relationships with individual birth weights and the odds of low birth weight status because a random component is added to the intercept ($u_0$). Essentially, this random component estimates a separate intercept for each county, allowing the fixed effect portion of the equation to completely control for between-county differences in the average level of the outcome, average birth weight for the continuous dependent variable and the odds of low birth weight status for the dichotomous dependent variable. All level-I (individual-level) covariates are centered about their county means, so that true within-county estimates are obtained. At level-II, continuous variables are centered about the grand-mean for ease of interpretation.

*Steps in the Analysis*

First, initial analyses using one-way analysis of variance (ANOVA) procedures test for differences in birth weights and the probability of low birth weight status at level-II. These tests report the overall variability among county means in the two outcomes of interest. Separate analyses are performed with rural-urban continuum codes, a dichotomous measure for the metro/nonmetro status of the infant's county of residence, and the percentage of the county population that is rural and population density using the continuous and dichotomous dependent variables.

Second, the next set of analyses consists of two-level random intercept models with fixed level-one covariates. The main feature of a random intercept model is that only the intercept in the level-I model is assumed to vary at level-II, all other covariates are constant (Raudenbush and Bryk 2002). Details of how these models are estimated are given below. The first model presented is for the continuous dependent variable of birth weight, and then the model specifications for the dichotomous dependent variables using Bernoulli estimation techniques, which predict the probability that an infant will be born low birth weight or not, are presented.

A fully unconditional, or null, model is estimated in order to partition the variance between the two levels in this analysis. Equation 1 specifies the equation for the model.

$Y_{ij} = \beta_{0j} + r_{ij}$

where

$\beta_{0j} = \gamma_{00} + u_j$ and $r_{ij} \sim N(0,\sigma^2)$; $u_j \sim N(0,\tau_{00})$ [Equation 1]

The results from this model separate the total variance in $Y_{ij}$ into within- and between-county components. $Y_{ij}$ represents the infant's birth weight for infant *i* in county *j*. Within this equation, $r_{ij}$ accounts for random error at the individual-level. Within-county (individual-level) variation is represented by $\sigma^2$ in the equation, while $\tau_{00}$ accounts for between-county variation. These two variance components are the amount of variance attributable to each of the two levels in the model.

Third, all level-I covariates are included in the next set of models as controls, and level-II variable are added in a nested model format. Level-I covariates are consistent across the models in order to control for individual characteristics on the outcome variable, since results from Chapter 3 indicate that individual-level characteristics explain 34.14 percent of the variation in individual birth weight and the odds of low birth weight status. Additionally, statistical adjustments for individual-level characteristics are crucial for two purposes in this analysis. First, individuals are not usually randomly assigned to the places they live and failure to control for individual characteristics may bias estimates of county-level effects. Second, if individual (level-I) characteristics are strongly related to birth weight, and in this case they are, controlling for level-I covariates will increase the precision of any estimates of county (level-II) characteristics.

Equation 2 presents the remaining model specification for this analysis. All level-I covariates, represented by $Y_{ij}$ in the equation, are held constant.

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + \beta_{3j}X_{3ij} + r_{ij}$$

and

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Rurality Characteristics}) + \gamma_{02}(\text{Socioeconomic Characteristics})$$
$$+ \gamma_{03}(\text{Social Capital Characteristics}) + \gamma_{04}(\text{Social Environment Characteristics})$$
$$+ \gamma_{05}(\text{Health Services Characteristics}) + u_0$$

$$\beta_{1j}X_{1ij} = \gamma_{10}(\text{Individual Biological Characteristics})$$
$$\beta_{2j}X_{2ij} = \gamma_{20}(\text{Individual Social Characteristics})$$
$$\beta_{3j}X_{3ij} = \gamma_{30}(\text{Individual Behavioral Characteristics}) \qquad \text{[Equation 2]}$$

Level-II measures are added in a nested manner, with each of the characteristics represented by $\beta_{0j}$ being added to the model with level-I controls. For the rurality characteristics in the model at level-II, separate analyses are conducted to see how different operationalizations of the concept rural vary in their association with birth weight and the odds of low birth weight status. Other level-II characteristics remain the same in all of the models. A population weight is assigned to the level-I covariates in the model to make the results generalizable to all infants born in 2001.

Finally, a different set of assumptions is used for the distribution of the dichotomous dependent variable in this analysis. The Bernoulli distribution is used for this set of analyses, because this estimation technique allows for a dependent variable that has a value of either zero or one, which indicates if the infant is low birth weight or not. Level-II models and level-I covariates remain the same with this model, only the distribution of the dependent variable changes, found in Equation 3.

$$Y_{ij} \mid \varphi_{ij} \sim B(m_{ij}, \varphi_{ij})$$

where

$E(Y_{ij} \mid \varphi_{ij}) = m_{ij}\,\varphi_{ij},$ $\quad Var(Y_{ij} \mid \varphi_{ij}) = m_{ij}\,\varphi_{ij}\,(1 - \varphi_{ij})$ [Equation 3]

In this equation, $Y_{ij}$ has a binomial distribution with $m_{ij}$ individuals and probability of low birth weight for each individual as $\varphi_{ij}$. The second part of the equation represents the expected value and variance of $Y_{ij}$. Therefore this set of models will estimate the probability of low birth weight status based on the level-I and level-II measures in the model. Nested models are used in a similar fashion for this set of analyses as presented above for the continuous dependent variable.

In the models examined in this research, the level-II coefficients represent the relationship between the level-II covariate of interest and value of $b_0$ for the outcome variables, birth weight or the odds of low birth weight status, which exists between counties. The level-I coefficients represent the within-county relationships between the individual-level covariates and the outcome variables, adjusting for the dependence of observations within counties.

## Findings

### Individual– and County–Level Characteristics

Table 4.2 presents the means or percentages and standard deviations for variables at level-I and level-II for all variables contained in the multilevel models. The mean birth weight for infants in this sample is 3,319.13 grams, or approximately 7.31 pounds. Individual birth weights range from 227.00 grams, or 0.50 pounds, to 5,443.00 grams which is equivalent to 12.20 pounds. As for the dichotomous dependent variable, 7.4 percent of infants in the population of births occurring in 2001 are born low birth weight (under 2,500 grams). Individual, or level-1, covariates are listed at the bottom of Table

4.2. Values in these tables are the same as the descriptive data from Table 3.2 in Chapter 3.

Level-II, or county, covariates are also shown in Table 4.2. As would be expected the majority of the population of births in 2001 (31 percent) live in the most metro county designation, which is central metro counties with populations of one million or more. The most nonmetro counties have the smallest percentage of the total population of births. For example, counties that are completely rural with a population less than 2,500 adjacent to metro counties have one percent of births for 2001. A little more than 21 percent of a county's population is rural, on average. In this sample, the percentage of the county population that is rural ranges from 0 to 93.42 percent. The population density for the counties in this analysis averages about 358 people per square kilometer, and this value ranges widely from 0.29 to 5,039.77 people per square kilometer.

Table 4.2: Weighted Means or Percentage and Standard Deviations at Level-II and Standard Errors at Level-I, Early Childhood Longitudinal Study-Birth Cohort; n=10,608

| | Mean or Percentage | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| *Dependent Variables* | | | | |
| Birth Weight in Kilograms | 3,319.13 | 874.40 | 227.00 | 5,443.00 |
| Low Birth Weight Status | 7.39 | 0.002 | | |
| *Level-II Covariates (County)* | | | | |
| **Residential Characteristics** | | | | |
| (0) Central metro, 1million or more | 31 | 0.46 | | |
| (1) Metro fringe, 1million or more [a] | 7 | 0.25 | | |
| (2) Metro, 250,000 – 1 million | 16 | 0.37 | | |
| (3) Metro, less than 250,000 | 11 | 0.31 | | |
| (4) Urban 20,000 plus, adjacent to metro | 6 | 0.23 | | |
| (5) Urban 20,000 plus, not adjacent to metro | 6 | 0.24 | | |
| (6) Urban 2,500-19,999, adjacent to metro | 10 | 0.30 | | |
| (7) Urban 2,500-19,999, not adj to metro | 11 | 0.32 | | |
| (8) Rural or less than 2,500, adj to metro | 1 | 0.11 | | |
| (9) Rural or less than 2,500, not adj to metro | 2 | 0.13 | | |
| Metropolitan County Status (1=metro) | 65 | 0.48 | | |
| Percent of County Population Rural | 21.42 | 22.88 | 0.00 | 93.42 |
| Population Density (pop/square kilometer) | 358.02 | 662.25 | 0.29 | 5,039.77 |
| **Socioeconomic Characteristics** | | | | |
| Gini Coefficient 2000 | 0.44 | 0.03 | 0.35 | 0.54 |
| Percent Black | 11.93 | 13.78 | 0.15 | 66.33 |
| Percent Hispanic | 10.01 | 12.83 | 0.41 | 78.27 |

-Table Continues-

| | | | | |
|---|---|---|---|---|
| Economic Factor Score | -0.15 | 1.04 | -2.51 | 3.07 |
| **Social Capital Characteristics** | | | | |
| Putnam Type Establishments | 12.93 | 4.53 | 3.26 | 28.64 |
| Olsen Type Establishments | 2.10 | 1.40 | 0.24 | 12.16 |
| **Social Environment Characteristics** | | | | |
| Crime Factor Score | -0.08 | 0.96 | -2.02 | 3.24 |
| **Health Services Characteristics** | | | | |
| Health Services Factor Score | -0.21 | 0.95 | -1.65 | 6.56 |
| Total Hospitals per 10,000 Population | 0.25 | 0.21 | 0.00 | 1.64 |
| *Level-I Covariates (Individuals)* | | | | |
| **Biological Characteristics** | | | | |
| Child Sex (1=male) | 51.05 | 0.50 | | |
| Gestational age (weeks) | 38.77 | 3.91 | 17.00 | 47.00 |
| Twin (1=yes) | 2.94 | 0.36 | | |
| Maternal Complications | 29.35 | 0.48 | | |
| Newborn Conditions | 6.53 | 0.33 | | |
| **Social Characteristics** | | | | |
| Mom Less than High School (reference) | 21.19 | 0.46 | | |
| Mom High School | 31.13 | 0.41 | | |
| Mom College or More | 47.68 | 0.36 | | |
| Income | 50,273.97 | 635.97 | 5,000.00 | 200,00.00 |
| Health Insurance (1=yes) | 53.02 | 0.50 | | |
| Mother's Age at Birth | 27.32 | 6.36 | 15 | 50 |
| Mother's Age at Birth Squared | 784.71 | 40.45 | 225 | 2,500 |
| White (reference) | 58.30 | 0.50 | | |
| Black | 13.60 | 0.37 | | |
| Hispanic | 21.92 | 0.38 | | |
| Asian | 3.42 | 0.34 | | |
| Other | 2.76 | 0.16 | | |
| Married (1=yes) | 67.50 | 0.47 | | |
| **Behavioral Characteristics** | | | | |
| Smoke while Pregnant | 10.82 | 0.31 | | |
| Drink while Pregnant | 0.43 | 0.08 | | |
| Number Prenatal Visits | 11.53 | 4.23 | 0 | 49 |
| Weight Gain – Less than 25 Pounds (ref) | 44.20 | 12.73 | | |
| Weight Gain – 25 to 34 Pounds | 29.06 | 13.42 | | |
| Weight Gain – 35 to 40 Pounds | 26.74 | 12.64 | | |
| Food Secure (1=yes) | 89.91 | 0.31 | | |
| Pregnancy Wanted (reference) | 84.48 | 0.46 | | |
| Pregnancy Not Wanted | 8.87 | 0.30 | | |
| Pregnancy Not Sure | 6.65 | 0.26 | | |
| WIC (1=yes) | 40.26 | 0.49 | | |

Income inequality, captured here by the Gini coefficient, has a mean value of 0.44, indicating that income distributions are somewhat unequally distributed across counties. Values for the Gini coefficient range from 0.35 to 0.54 for the counties included in this sample. The national value for the Gini coefficient in 2000 is 0.462, which is slightly higher than the value for the counties used in this analysis (U.S. Census

Bureau 2004b). Almost 12 percent of a county's population, on average, is composed of African Americans, ranging from 0.15 to 66.33 percent, while a little more than 10 percent of a county's population on average consists of Hispanics. The percentage of county residents that are Hispanic ranges from 0.41 percent to 78.27 percent.

A larger number of Putnam-type establishments is found in each county (12.93) than Olsen-Type establishments (2.10), on average. This most likely reflects the greater number of recreational, religious, and social types of activities for a given population compared to the total number of business-type associations. The range for the total number of hospitals in the county per 10,000 residents is small and has an average value of 0.25 hospitals per county for this sample. Overall values of variables at the county-level used in this sample vary from values for many of these variables when looking at all counties in the United States. Table 4.3 displays means, standard deviations, and minimum and maximum values for the entire US in 2000 for selected county-level variables found in Table 4.3.

Table 4.3: Means and Standard Deviations for Selected Level-II Variables for All Counties in the US, 2000

| | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Percent of County Population Rural | 58.72 | 31.62 | 0 | 100.00 |
| Population Density (pop/square km) | 83.72 | 581.61 | 0.10 | 20,914.79 |
| Gini Coefficient 2000 | 0.44 | 0.04 | 0.31 | 0.61 |
| Percent Black | 8.68 | 14.39 | 0 | 86.13 |
| Percent Hispanic | 8.37 | 18.56 | 0 | 99.69 |
| Putnam Type Establishments | 16.52 | 8.47 | 0 | 113.92 |
| Olsen Type Establishments | 1.85 | 1.61 | 0 | 22.45 |
| Total Hospitals per 10,000 Population | 0.54 | 0.80 | 0 | 8.37 |

The average mean value is very different for many of the variables when comparing all counties in the U.S. to counties used in this analysis. The minimum and maximum for variables in Table 4.3 are also quite different. The percentage of individuals for the sample used in this analysis is largely from metropolitan counties, as a result, many of the other county-level variables are likely to represent characteristics of metro county populations. Differences in resources across counties based on these measures are posited to lead to variation in individual birth weights and low birth weight status, specifically with reference to rurality. Variation in birth weight due to rurality is explored next.

**Rurality and Birth Weight**

Initial one-way analysis of variance (ANOVA) tests were conducted to see if birth weights vary based on the rural-urban continuum code assigned to the infant's county of residence. Table 4.4 presents results from this analysis based on the population of births for 2001. The significance level of the F-statistic (F=16.749) indicates that variation in birth weights do exist based on the rural-urban continuum code assigned to the infant's county of residence. When the analysis is weighted to all births occurring in 2001, the mean birth weight for all infants is 3,315.43 grams. Birth weights in metro counties with a population between 250,000 and one million (3,267.77 grams) and metro counties with a population less than 250,000 (3,312.61 grams) are lower than the total population. As for nonmetro designations, nonmetro counties with an urban population of 20,000 or more and not adjacent to a metro county and the most rural designation have birth weights that are slightly lower than the mean birth weight for all infants. The highest mean birth weight is for infants in nonmetro counties with an urban population of 20,000 or more, adjacent to a metro county. Infants in this type of nonmetro county tend to weight about 60 grams more than the average infant in the population. Differences in birth weights for each of the county designations are fairly small, but the variation is statistically significant.

Table 4.4: ANOVA for Overall Birth Weight in Grams by Rural-Urban Continuum Codes, Early Childhood Longitudinal Study – Birth Cohort; n=10,608

| Rural-Urban Continuum Codes | Mean | Standard Deviation | Number of Cases |
|---|---|---|---|
| *With Weighting* | | | |
| (0) Central metro, 1million or more | 3,316.08 | 599.97 | 4,763 |
| (1) Metro fringe, 1million or more | 3,334.47 | 588.37 | 782 |
| (2) Metro, 250,000 – 1 million | 3,267.77 | 637.88 | 1,732 |
| (3) Metro, less than 250,000 | 3,312.61 | 584.99 | 878 |
| (4) Urban 20,000 plus, adjacent to metro | 3,375.49 | 843.44 | 395 |
| (5) Urban 20,000 plus, not adjacent to metro | 3,305.83 | 508.28 | 311 |
| (6) Urban 2,500-19,999, adjacent to metro | 3,362.60 | 555.83 | 743 |
| (7) Urban 2,500-19,999, not adjacent to metro | 3,327.76 | 558.39 | 723 |
| (8) Rural or less than 2,500, adjacent to metro | 3,359.73 | 560.34 | 138 |
| (9) Rural or less than 2,500, not adjacent to metro | 3,313.00 | 502.10 | 143 |
| *Average Birth Weight for the Population of Births* | *3,315.43* | *593.59* | *10,608* |
| $F=16.749$, $p<0.001$ | | | |

**Individual- and County-Level Characteristics and Birth Weight**

Debates over weighting data when using multilevel methods are unresolved. The weighting option in HLM 6 allows for a base weight to be included at level-I (individual-level). Unweighted models are estimated to calculate variance components since HLM does not provide variance components with their weighted output. All models in this chapter are weighted using the base population weight provided in the Early Childhood Longitudinal Study – Birth Cohort to account for over sampling of certain racial/ethnic groups, twins, and low birth weight infants in the sample. Results from the weighted models presented here more accurately reflect estimates based on the composition of the population of births occurring in 2001.

To examine the total amount of variation in overall birth weights, a fully unconditional, or null, model is examined. As previously mentioned, results from this model separate the total variance into within- and between-county components. The results, not shown here, indicate that there is a great deal more within-county (individual) than between-county (mean across counties) variation. About five percent of total variation in overall birth weights is attributed to between-county differences ($\tau_{00}/(\sigma^2 + \tau_{00}) = 39{,}642.81/771{,}817.42 = 0.051$), while within-county individual differences account for the remainder of the variation ($\sigma^2/(\sigma^2 + \tau_{00}) = 732{,}174.62/771{,}817.42 = 0.949$). The large amount of variation between individuals is expected since individual health outcomes range widely between people. The intercept in the null model, or average birth weight for infants, is 3,316.95 grams, or approximately 7.30 pounds.

Rural-urban continuum codes are added in Model 1 in Table 4.5a for a random intercept model. Essentially only birth weight is regressed on the various rurality codes with controls for individual-level covariates. Results from this model indicate that six rural-urban continuum code designations have a statistically significant relationship with average birth weights with individual-level variables controlled. Birth weights in metro counties with a population of 250,000 to one millions are 112.86 grams less than birth weights for infants in counties with the most metro county designation. The remaining significant relationships between rural-urban continuum code designations and birth weight are found for nonmetro counties, and each of the relationships is positive. Infants in nonmetro counties with an urban population of 20,000 or more that is adjacent to metro counties have average birth weights that are 114.09 grams more than birth weights of infants in counties with the most metro county designation. Infants in nonmetro counties with an urban population between 2,500 and 19,999 residents adjacent to metro counties have birth weights that are 132.32 grams higher than infants in the most metro counties. This county designation has the highest average birth weight for all county designations in Model 1. Only county designations 1 and 3 of the metro counties and designation 9 of the nonmetro counties have average birth weights that do not significantly differ from birth weights in central metro counties with a population of one million or more, the reference category.

Relationships for individual-level variables in this model are as expected. All of the biological characteristics remain significant with the addition of residential characteristics at level-II in Model 1. Higher birth weights are found for mothers that have access to private health insurance. Mother's age at the time of birth has a similar relationship in this model as in the individual-level models presented in Chapter 3, which indicates that the shape of the relationship with age of the mother at the time of birth has an inverse U-shape. Black, Asian, and infants of other or multiple races have birth weights that are lower than white infants on average. Birth weights are lower for infants whose mothers smoke while they are pregnant with the child. The number of prenatal visits the mother attends and weight gain of at least twenty-five pounds during pregnancy have positive relationships with birth weight. These relationships for the individual-level control variables are maintained in each of the remaining models with the addition of other county-level variables. Model 1 accounts for 57.60 percent of the variability in individual birth weights.

Table 4.5a: Random Intercept Models of Birth Weight in Grams on County- and Individual-Level Characteristics, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Weighted Coefficient (Standard Error)

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | 3070.73 (18.99)** | 3084.56 (18.04)** | 3101.01 (20.62)** |
| Level-II (County Characteristics) | | | |
| **Residential Characteristics** | | | |
| (1) Metro fringe, 1million or more [a] | 5.96 (61.45) | -8.14 (46.73) | -15.43 (46.57) |
| (2) Metro, 250,000 – 1 million | -112.86 (47.16)* | -116.09 (38.36)* | -131.64 (38.64)** |
| (3) Metro, less than 250,000 | 14.00 (49.72) | 5.29 (35.13) | -18.94 (38.16) |
| (4) Urban 20,000+, adjacent to metro | 114.09 (43.09)* | 68.12 (40.60)† | 48.48 (48.33) |
| (5) Urban 20,000 +, not adj to metro | 129.52 (38.77)** | 80.73 (42.25)† | 52.25 (45.56) |
| (6) Urban 2,500-19,999, adj to metro | 132.32 (42.24)* | 97.63 (46.24)* | 65.40 (52.53) |
| (7) Urban 2,500-19,999, not adj to metro | 98.59 (35.74)* | 76.90 (39.46)† | 43.30 (42.79) |
| (8) Rural or <2,500, adjacent to metro | 97.12 (47.78)* | 17.90 (53.51) | -8.20 (47.73) |
| (9) Rural or <2,500, not adj to metro | 36.07 (40.53) | 19.98 (58.05) | -16.25 (62.19) |
| **Socioeconomic Characteristics** | | | |
| Gini Coefficient 2000 | | -651.62 (381.84)† | -809.39 (418.25)† |
| Percent Black | | -5.52 (1.01)** | -5.90 (1.01)** |
| Percent Hispanic | | -0.02 (0.85) | -0.40 (0.88) |
| Economic Factor Score | | | -20.69 (12.63) |
| **Social Capital Characteristics** | | | |
| Putnam Type Establishments | | | |
| Olsen Type Establishments | | | |
| **Social Environment Characteristics** | | | |
| Crime Factor Score | | | |
| **Health Services Characteristics** | | | |
| Health Services Factor Score | | | |
| Total Hospitals per 10,000 Population | | | |
| Level-I (Individual) Characteristics | | | |
| **Biological Characteristics** | | | |
| Child Sex (1=male) | 118.88 (10.99)** | 118.87 (10.98)** | 118.94 (10.98)** |
| Gestational age (weeks) | 98.97 (3.34)** | 99.08 (3.36 )** | 99.109 (3.36)** |
| Twin (1=yes) | -628.36 (17.85)** | -624.65 (17.85)** | -625.28 (18.00)** |
| Maternal Complications | -41.68 (16.25)* | -41.82 (16.23)* | -41.61 (16.24)* |
| Newborn Conditions | -163.54 (32.33)** | -162.46 (32.23)** | -162.55 (32.23)** |
| **Social Characteristics** | | | |
| Mom High School (ref=less than HS) | -13.09 (17.26) | -13.34 (17.26) | -13.43 (17.26) |
| Mom College or More | -19.04 (17.33) | -19.70 (17.29) | -19.68 (17.28) |
| Income | 0.0003 (0.0002) | 0.0003 (0.0002) | 0.0003 (0.0002) |
| Health Insurance (1=yes) | 35.36 (16.49)* | 34.91 (16.46)* | 34.89 (16.46)* |
| Mother's Age at Birth | 30.23 (7.70)** | 30.45 (7.70)** | 30.51 (7.71)** |
| Mother's Age at Birth Squared | -0.41 (0.14)* | -0.42 (0.14)* | -0.42 (0.14)* |
| Black (reference=white) | -119.72 (19.59)** | -121.48 (19.54)** | -121.45 (19.54)** |
| Hispanic | -17.52 (21.32) | -18.33 (21.25) | -18.50 (21.25) |
| Asian | -195.38 (18.65)** | -194.04 (18.64)** | -196.21 (18.61)** |
| Other | -91.01 (37.22)* | -90.57 (37.18)* | -90.24 (37.23)* |
| Married (1=yes) | 17.22 (17.13) | 17.78 (17.12) | 17.69 (17.13) |
| **Behavioral Characteristics** | | | |
| Smoke while Pregnant | -186.91 (20.71)** | -187.93 (20.75)** | -188.09 (20.75)** |
| Drink while Pregnant | -29.54 (58.39) | -26.21 (58.47) | -26.18 (58.52) |
| Number Prenatal Visits | 4.84 (1.73)* | 4.83 (1.73)* | 4.82 (1.73)* |
| Weight Gain | 97.53 (8.33)** | 91.40 (8.29)** | 91.33 (8.29)** |
| Food Secure (1=yes) | 7.50 (22.55) | 7.90 (22.59) | 7.87 (22.60) |
| Preg Not Wanted (ref=wanted preg) | 17.02 (26.03) | 17.67 (25.97) | 17.75 (25.99) |
| Pregnancy Not Sure | 26.91 (24.67) | 26.87 (24.72) | 26.81 (24.71) |
| WIC (1=yes) | -4.44 (17.89) | -3.75 (17.92 ) | -3.91 (17.92) |
| $R^2$ | 0.5760 | 0.5955 | 0.5969 |

** p <.001 * p <.05 † <.10
[a] Reference category for the rural-urban continuum codes is central counties of metro areas of 1 million population or more

Socioeconomic characteristics of the infant's county of residence are added in Models 2 and 3. The Gini coefficient for each county in this analysis represents the overall inequality in income distribution for that particular county. When this variable is added to the rural-urban continuum codes in Model 2, it has a significant negative relationship (-651.62) with birth weights as would be expected. This result also supports the relative-income hypothesis that states that high levels of income inequality should increase poor health outcomes. The percentage of black residents in a county has a significant negative relationship with birth weight. If the population of a county is twenty percent black then the average birth weight in that county will be 110.40 grams less for individual infants in that county than counties without black residents (-5.52*20=110.40). Most relationships between the rural-urban continuum code designations and birth weight remain the same, except for designation 8. However, some of these relationships lose their level of significance to $p \leq 0.10$. No statistically significant relationship remains for this designation and birth weight with the addition of socioeconomic characteristics in Model 2. The only negative relationship between the continuum code designations and birth weight is found for infants in metro counties with a population between 250,000 and one million.

The addition of the economic factor score variable in Model 3 does not have a statistically significant relationship with birth weight. However, with this variable added to the model only infants in metro counties with a population of 250,000 to one million have lower birth weights than infants in counties with the most metro county designation. All other rural-urban continuum code designations do not have birth weights that differ significantly from birth weights for infants in central counties of metro areas with a population of one million or more. Other relationships for both level-I and level-II variables remain the same in Model 3, and 59.69 percent of the variance in average birth weights is explained by this model.

Table 4.5b presents the remaining three models that incorporate other county-level characteristics. Model 4 in Table 4.5b adds in social capital characteristics at the county-level, both Putnam- and Olsen-type establishments. As the number of Olsen-type establishments increases, average birth weights for infants in those counties are lowered. No statistically significant relationship is found between the number of Putnam-type establishments, which measures the number of social organizations and activities, and average birth weight for infants. All other statistically significant relationships remain the same as in Model 3 in Table 4.5a.

A measure of the social environment is added in Model 5 in the form of a factor score. This factor score is composed of the violent crime rate and property crime rate for the county. The addition of this factor score in Model 5 is not statistically significant in determining average birth weights. However when health services characteristics are incorporated into Model 6, a positive significant relationship is found between the crime factor score and birth weight. The health services factor score, which is made up of various types of medical personnel including the total number of medical doctors, pediatricians, obstetricians/gynecologists, and emergency medical personnel in the county per 10,000 residents, has a negative significant relationship with average individual birth weight. A significant negative relationship between birth weight and the number of Olsen-type establishments per 10,000 residents in the county, as well as for the percentage of black residents in the county and birth weight, remains with all variables

Table 4.5b: Random Intercept Models of Birth Weight in Grams on County- and Individual-Level Characteristics, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Weighted Coefficient (Standard Error)

| | Model 4 | Model 5 | Model 6 |
|---|---|---|---|
| Intercept | 3103.28 (21.33)** | 3099.13 (21.52)** | 3111.29 (20.40)** |
| Level-II (County Characteristics) | | | |
| **Residential Characteristics** | | | |
| (1) Metro fringe, 1million or more [a] | -25.68 (46.84) | -16.73 (47.68) | -23.84 (43.75) |
| (2) Metro, 250,000 – 1 million | -133.35 (40.24)** | -127.70 (40.26)* | -132.18 (38.94)** |
| (3) Metro, less than 250,000 | -24.08 (39.73) | -22.53 (40.39) | -30.02 (39.22) |
| (4) Urban 20,000+, adjacent to metro | 58.98 (39.94) | 61.37 (40.99) | 52.65 (41.03) |
| (5) Urban 20,000 +, not adj to metro | 51.31 (47.08) | 60.99 (49.51) | 45.10 (51.24) |
| (6) Urban 2,500-19,999, adj to metro | 52.31 (49.68) | 60.96 (48.41) | 37.64 (47.84) |
| (7) Urban 2,500-19,999, not adj to metro | 37.20 (40.92) | 47.93 (41.53) | 19.99 (40.89) |
| (8) Rural or <2,500, adjacent to metro | 4.31 (38.13) | 10.60 (40.66) | -61.61 (42.23) |
| (9) Rural or <2,500, not adj to metro | -19.83 (56.00) | -4.57 (56.01) | -48.47 (61.08) |
| **Socioeconomic Characteristics** | | | |
| Gini Coefficient 2000 | -792.40 (414.41)† | -729.29 (407.51)† | -185.90 (454.05) |
| Percent Black | -5.74 (0.99)** | -6.20 (1.03)** | -5.88 (1.03)** |
| Percent Hispanic | -0.23 (1.02) | -0.28 (1.03) | -0.18 (0.93) |
| Economic Factor Score | -12.85 (13.37) | -5.94 (13.55) | 24.99 (15.24) |
| **Social Capital Characteristics** | | | |
| Putnam Type Establishments | 2.86 (3.49) | 2.99 (3.47) | 3.81 (3.78) |
| Olsen Type Establishments | -20.08 (8.66)* | -21.54 (8.95)* | -19.40 (7.76)* |
| **Social Environment Characteristics** | | | |
| Crime Factor Score | | 17.70 (10.90) | 23.59 (10.77)* |
| **Health Services Characteristics** | | | |
| Health Services Factor Score | | | -51.26 (12.71)** |
| Total Hospitals per 10,000 Population | | | 112.24 (84.82) |
| Level-I (Individual) Characteristics | | | |
| **Biological Characteristics** | | | |
| Child Sex (1=male) | 118.94 (10.98)** | 118.89 (10.98)** | 118.85 (10.98)** |
| Gestational age (weeks) | 99.18 (3.36)** | 99.18 (3.36)** | 99.28 (3.36)** |
| Twin (1=yes) | -625.12 (18.08)** | -625.08 (18.12)** | -626.58 (18.18)** |
| Maternal Complications | -41.53 (16.24)* | -41.60 (16.24)* | -41.78 (16.23)* |
| Newborn Conditions | -163.17 (32.21)** | -162.98 (32.22 )** | -163.07 (32.21)** |
| **Social Characteristics** | | | |
| Mom High School (ref=less than HS) | -13.35 (17.27) | -13.29 (17.27) | -13.07 (17.27) |
| Mom College or More | -19.57 (17.27) | -19.52 (17.29) | -19.37 (17.29) |
| Income | 0.0003 (0.0002) | 0.0003 (0.0002) | 0.0003 (0.0002) |
| Health Insurance (1=yes) | 34.75 (16.47)* | 34.78 (16.48)* | 34.68 (16.50)* |
| Mother's Age at Birth | 30.45 (7.71)** | 30.44 (7.71 )** | 30.35 (7.71)** |
| Mother's Age at Birth Squared | -0.42 (0.14)* | -0.42 (0.14)* | -0.41 (0.14)* |
| Black (reference=white) | -121.19 (19.54)** | -121.32 (19.54)** | -121.36 (19.58)** |
| Hispanic | -18.35 (21.26) | -18.47 (21.26) | -18.51 (21.26) |
| Asian | -196.77 (18.62)** | -195.97 (18.66)** | -196.47 (18.56)** |
| Other | -89.96 (37.26)* | -89.61 (37.26 )* | -89.14 (37.25)* |
| Married (1=yes) | 17.81 (17.13) | 17.85 (17.14) | 17.64 (17.12) |
| **Behavioral Characteristics** | | | |
| Smoke while Pregnant | -188.55 (20.78)** | -188.47 (20.78)** | -188.45 (20.77)** |
| Drink while Pregnant | -26.29 (58.43) | -26.05 (58.44) | -23.94 (58.37) |
| Number Prenatal Visits | 4.80 (1.73)* | 4.82 (1.73)* | 4.85 (1.73)* |
| Weight Gain | 91.39 (8.30)** | 91.45 (8.31)** | 91.22 (8.30)** |
| Food Secure (1=yes) | 7.98 (22.60) | 7.88 (22.60 ) | 8.03 (22.61) |
| Preg Not Wanted (ref=wanted preg) | 17.75 (25.98) | 17.74 (25.98) | 17.63 (26.02) |
| Pregnancy Not Sure | 26.48 (24.70) | 26.59 (24.70) | 26.36 (24.71) |
| WIC (1=yes) | -3.95 (17.92) | -4.03 (17.93) | -3.94 (17.91) |
| $R^2$ | 0.5976 | 0.5979 | 0.6024 |

** p $\leq$.001 * p $\leq$.05 † $\leq$.10 [a] Reference category is central counties of metro areas of 1 million population or more included in Model 6. Income inequality becomes statistically non-significant with the addition of health services characteristics in Model 6. The only rural-urban continuum code to remain statistically significant with all variables in the model is for infants in metro counties with a population between 250,000 and one million. Infants in these counties have birth weights that are 132.18 grams lower than infants in central counties of metro areas with a population of one million or more. Relationships with level-I (individual characteristics) covariates are consistent in these six models. The overall variation explained in this two-level random intercept model using rural-urban continuum codes as the measure of rurality characteristics is 60.24 percent.

## Other Measures of Residential Characteristics and Birth Weight

*Metropolitan/Nonmetropolitan County Status*

As a point of comparison, each of the models just presented was examined with a dichotomous measure of metro/nonmetro residence status in order to test whether variability is lost when this measure is used. Initial one-way analysis of variance (ANOVA) procedures indicate that a statistically significant difference in birth weight does exist based on the metro/nonmetro designation of an infant's county of residence.

Table 4.6: ANOVA for Birth Weight in Grams by Metro/Nonmetropolitan Status of the Infant's County of Residence

| Metro/Nonmetropolitan Status | Mean | Standard Deviation | Number of Cases |
|---|---|---|---|
| *With Weighting* | | | |
| Metropolitan Counties | 3,306.89 | 606.49 | 8,155 |
| Nonmetropolitan Counties | 3,343.91 | 547.41 | 2,453 |
| *Average Birth Weight for the Population of Births* | *3,315.43* | *593.59* | *10,608* |
| F=79.324, p<0.001 | | | |

Statistically significant differences are found when weighting to account for the sample design in the ECLS-B. In the weighted ANOVA, on average nonmetro infants weigh approximately 37 grams more than their metro counterparts.

Results from the final model (Model 6 in Table 4.5b) using all county-level characteristics and controlling individual-level covariates with the metro/nonmetro dichotomous residence variable are presented in Table 4.7. Individual infants in metro counties weigh 110.72 grams less than infants in nonmetro counties. A similar relationship between birth weight and the percentage of black residents in a county is found using the rural-urban continuum codes and the dichotomous measure of metro/nonmetro status. The economic factor score has a significant positive relationship in this model, while no statistically significant relationship was found for this variable when the rural-urban continuum code designations are used. This may be due to the designations capturing certain economic dimensions of counties by incorporating measures of adjacency which could be important for employment opportunities. Other relationships in this model presented in Table 4.7 remain similar to those found in Model 6 in Table 4.5b. For example, a significant negative relationship is found between the health services factor score and birth weight. An unusual relationship is observed between the crime factors score and birth weight. It appears that as crime increases within the county, birth weights increase on average. This factor score may be serving as a proxy for other metropolitan related characteristics of counties that are common in areas with high population concentrations.

Although many of the relationships and coefficients are similar between these models, the significant negative relationship between metro county status and individual birth weight is fairly consistent with the results from models found in Table 4.5b.

Table 4.7: Random Intercept Model of Birth Weight in Grams on County- and Individual-Level Characteristics with Dichotomous Measures of Metropolitan Status, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Weighted Coefficient (Standard Error)

| | Model 6 (Full Model) |
|---|---|
| Intercept | 3158.85 (85)** |
| Level-II (County Characteristics) | |
| **Residential Characteristics** | |
| Metropolitan County Status (1=metro) | -100.72 (31.34)** |
| **Socioeconomic Characteristics** | |
| Gini Coefficient 2000 | -322.87 (489.98) |
| Percent Black | -5.29 (1.08)** |
| Percent Hispanic | 0.19 (1.01) |
| Economic Factor Score | 39.99 (15.77)* |
| **Social Capital Characteristics** | |
| Putnam Type Establishments | 1.87 (3.42) |
| Olsen Type Establishments | -21.68 (9.21)* |
| **Social Environment Characteristics** | |
| Crime Factor Score | 29.52 (12.32)* |
| **Health Services Characteristics** | |
| Health Services Factor Score | -48.59 (14.83)** |
| Total Hospitals per 10,000 Population | 86.55 (78.23) |
| Level-I (Individual) Characteristics | |
| **Biological Characteristics** | |
| Child Sex (1=male) | 118.99 (10.97)** |
| Gestational age (weeks) | 99.12 (3.34 )** |
| Twin (1=yes) | -627.42 (18.30)** |
| Maternal Complications | -41.82 (16.24)* |
| Newborn Conditions | -161.90 (32.20)** |
| **Social Characteristics** | |
| Mom High School (ref=less than HS) | -12.77 (17.24) |
| Mom College or More | -19.49 (17.22) |
| Income | 0.0003 (0.0002) |
| Health Insurance (1=yes) | 34.66 (16.49)* |
| Mother's Age at Birth | 30.37 (7.69 )** |
| Mother's Age at Birth Squared | -0.41 (0.14)* |
| Black (reference=white) | -120.85 (19.63)** |
| Hispanic | -18.25 (21.28) |
| Asian | -199.54 (18.56)** |
| Other | -89.81 (37.27)* |
| Married (1=yes) | 17.86 (17.14) |
| **Behavioral Characteristics** | |
| Smoke while Pregnant | -188.00 (20.81)** |
| Drink while Pregnant | -25.14 (58.06) |
| Number Prenatal Visits | 4.85 (1.73)* |
| Weight Gain | 91.24 (8.30)** |
| Food Secure (1=yes) | 7.71 (22.62) |
| Preg Not Wanted (ref=wanted preg) | 17.64 (26.01) |
| Pregnancy Not Sure | 26.16 (24.69) |
| WIC (1=yes) | -3.88 (17.92) |
| $R^2$ | 0.5974 |

** p ≤.001 * p ≤.05 † ≤.10

While large differences are not found across the rural-urban continuum code designations when all county-level characteristics are in the full model in Table 4.5b, results using a dichotomous measure of metro/nonmetro county status does not capture the slight variations that occur in individual birth weight in metro counties.

*Percentage of County Population that is Rural and Population Density*

One final set of residential characteristics is used to estimate the full model to determine how individual- and county-level characteristics influence individual birth weight. Table 4.8 presents results from the full model replacing the residential characteristics with the percentage of the county population that is rural and a measure of population density for the county. As the percentage of the county population that is rural increases, birth weights will be higher for individual infants in those counties. For example, a county with a rural population constituting 30 percent of the population would expect to have infants that weight 60.6 grams more than a county with no rural population (2.02 * 30 = 60.6). A measure of the population density for the infant's county of residence does not have a statistically significant relationship with birth weight. Relationships with other county-level characteristics remain the same for the models in Table 4.7 and Table 4.8. Several findings persist across these models. Lower birth weights are found for infants that live in counties that have a high percentage of black residents. A larger number of Olsen-type establishments in the county lower birth weight. A significant negative association between the health services factor score and birth weight also remains across all of these models.

Results from these three models reveal different types of relationships for nonmetro residents depending on the measure of rurality used. In Model 6 in Table 4.5b, infants in nonmetro counties do not have birth weights that are statistically different than infants in central metro counties with a population of one million or more.

Table 4.8: Random Intercept Model of Birth Weight in Grams on County- and Individual-Level Characteristics with Percent Rural Population and Population Density, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Weighted Coefficient (Standard Error)

| | Model 6 (Full Model) |
|---|---|
| Intercept | 3093.81 (11.45)** |
| Level-II (County Characteristics) | |
| **Residential Characteristics** | |
| Percent of County Population Rural | 2.02 (0.95)* |
| Population Density | 0.01 (0.01) |
| **Socioeconomic Characteristics** | |
| Gini Coefficient 2000 | -366.71 (499.32) |
| Percent Black | -5.65 (1.12)** |
| Percent Hispanic | 0.93 (1.12) |
| Economic Factor Score | 40.40 (16.53)* |
| **Social Capital Characteristics** | |
| Putnam Type Establishments | 1.30 (3.70) |
| Olsen Type Establishments | -17.07 (10.14)† |
| **Social Environment Characteristics** | |
| Crime Factor Score | 30.06 (12.24)* |
| **Health Services Characteristics** | |
| Health Services Factor Score | -45.56 (14.90)* |
| Total Hospitals per 10,000 Population | 107.61 (83.90) |
| Level-I (Individual) Characteristics | |
| **Biological Characteristics** | |
| Child Sex (1=male) | 119.06 (10.98)** |
| Gestational age (weeks) | 99.09 (3.34)** |
| Twin (1=yes) | -628.38 (18.43)** |
| Maternal Complications | -41.85 (16.25)* |
| Newborn Conditions | -162.24 (32.21)** |
| **Social Characteristics** | |
| Mom High School (ref=less than HS) | -12.63 (17.25) |
| Mom College or More | -19.55 (17.21) |
| Income | 0.0003 (0.0002) |
| Health Insurance (1=yes) | 34.62 (16.48)* |
| Mother's Age at Birth | 30.30 (7.69)** |
| Mother's Age at Birth Squared | -0.41 (0.14)* |
| Black (reference=white) | -120.33 (19.63)** |
| Hispanic | -17.98 (21.30) |
| Asian | -197.88 (18.63)** |
| Other | -89.56 (37.38)* |
| Married (1=yes) | 17.99 (17.13) |
| **Behavioral Characteristics** | |
| Smoke while Pregnant | -187.92 (20.86)** |
| Drink while Pregnant | -23.73 (58.20) |
| Number Prenatal Visits | 4.87 (1.73)* |
| Weight Gain | 91.33 (8.31)** |
| Food Secure (1=yes) | 7.47 (22.65) |
| Preg Not Wanted (ref=wanted preg) | 17.83 (26.01) |
| Pregnancy Not Sure | 25.97 (24.64) |
| WIC (1=yes) | -3.87 (17.90) |
| $R^2$ | 0.5969 |

** p ≤.001 * p ≤.05 † ≤.10

However, infants in metro counties with a population between 250,000 and one million weigh 132.18 grams less at birth than infants born in the most metro counties with a population of one million or more.

Results from Table 4.7 indicate that individual infants in metro counties weigh 100.72 grams less at birth than infants born in nonmetro counties. Yet infants born in a county with a high percentage of the county population being rural have higher birth weights than infants born in a county with no rural population based on the results found in Table 4.8. These results suggest that the measure of rurality used will lead to different relationships with average birth weights, even when other county-level characteristics and individual-level controls are the same.

**Low Birth Weight Status and Multiple Levels of Rurality**

Models in the previous section detailed individual- and county-level covariates and how they are associated with variation in birth weights. Yet the relationships established in the previous models do not speak specifically to how these measures predict the odds of low birth weight status for individual infants in the population. The set of analyses in this section use multilevel logistic regression methods with Bernoulli estimation techniques in order to determine how individual and structural characteristics are associated with the odds of infants being born low birth weight, or less than 2,500 grams.

Initial tests examining variation in low birth weight status by residence indicate that significant variation does exist based on the rural-urban continuum code designation for the infant's county of residence. Table 4.9 presents results of the one-way analysis of variance (ANOVA) test. In the model with weighting to account for the oversampling of certain infants in the ECLS-B sample, a statistically significant difference exists in the probability of an infant being born low birth weight status between the rural-urban continuum code designations.

Table 4.9: ANOVA for Dichotomous Low Birth Weight Variable by Rural/Urban Continuum Codes (1=low birth weight), Early Childhood Longitudinal Study – Birth Cohort; n=10,608

| Rural-Urban Continuum Codes | Mean | Standard Deviation | Number of Cases |
|---|---|---|---|
| *With Weighting* | | | |
| (0) Central metro, 1million or more | 0.076 | 0.27 | 4,763 |
| (1) Metro fringe, 1million or more | 0.069 | 0.25 | 782 |
| (2) Metro, 250,000 – 1 million | 0.085 | 0.29 | 1,732 |
| (3) Metro, less than 250,000 | 0.083 | 0.26 | 878 |
| (4) Urban 20,000 plus, adjacent to metro | 0.056 | 0.25 | 395 |
| (5) Urban 20,000 plus, not adjacent to metro | 0.048 | 0.22 | 311 |
| (6) Urban 2,500-19,999, adjacent to metro | 0.050 | 0.24 | 743 |
| (7) Urban 2,500-19,999, not adjacent to metro | 0.052 | 0.24 | 723 |
| (8) Rural or less than 2,500, adjacent to metro | 0.053 | 0.26 | 138 |
| (9) Rural or less than 2,500, not adjacent to metro | 0.064 | 0.25 | 143 |
| *Average Probability for the Population of Births* | *0.074* | *0.26* | *10,608* |

F=13.060, p<0.001

Almost seven and a half percent of infants in the weighted data are likely to be born low birth weight. Metro counties with a population between 250,000 and one million have the highest probability that an infant will be born low birth weight, and infants in nonmetro counties with an urban population of 20,000 or more not adjacent to a metro county have the lowest probability of individual infants being of low birth weight status.

**Low Birth Weight Status and County- and Individual-Characteristics**

Variance components using Bernoulli estimation for multilevel logistic regression in HLM 6 are not estimated in the same manner as variance components with a continuous dependent variable. Results in this section will simply report odds ratios for each of the variables at the county- and individual-levels. Models are estimated in a nested manner, similar to the models with a continuous dependent variable. The null model, results not presented here, has an intercept of -2.53 (odds ratio=0.08) that is statistically significant at the $p \leq 0.001$ level. This value indicates that the vast majority of infants in the population are of normal birth weight.

Table 4.10a presents results from the first set of county-level variables estimated in predicting the odds of low birth weight with controls for all level-I covariates. Model 1 includes only rural-urban continuum code designations as the measure of residential characteristics for the infant's county of residence. Metro counties with a population of 250,000 to one million residents are 1.60 times more likely to have infants that are low birth weight compared to infants in the most metro county designation with a population of one million or more. Three nonmetro counties have statistically significant odds ratios that indicate that infants in these county designations are less likely to be low birth weight compared to infants in metro counties with a central core population of one million or more. Infants in nonmetro counties with an urban population of 20,000 or more and not adjacent to a metro county are two-thirds less likely to be born low birth weight than infants in core metro counties with a population of one million or greater. Infants born to mothers in counties with an urban population between 2,500 and 19,999 residents adjacent to a metro county and nonmetro counties with an urban population

Table 4.10a: Random Intercept Models of Dichotomous Low Birth Weight Variable (1=yes) on County- and Individual-Level Characteristics, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Odds Ratio (Standard Error)

| | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | 0.10 (0.08)** | 0.10 (0.08)** | 0.09 (0.10)** |
| Level-II (County Characteristics) | | | |
| **Residential Characteristics** | | | |
| (1) Metro fringe, 1million or more [a] | 0.80 (0.18) | 0.81 (0.15) | 0.44 (0.18) |
| (2) Metro, 250,000 – 1 million | 1.60 (0.21)* | 1.61 (0.15)* | 1.77 (0.15)** |
| (3) Metro, less than 250,000 | 0.93 (0.25) | 0.89 (0.22) | 1.03 (0.22) |
| (4) Urban 20,000+, adjacent to metro | 0.75 (0.26) | 0.96 (0.24) | 1.10 (0.25) |
| (5) Urban 20,000 +, not adj to metro | 0.37 (0.26)** | 0.45 (0.36)* | 0.53 (0.35)† |
| (6) Urban 2,500-19,999, adj to metro | 0.46 (0.24)* | 0.53 (0.25)* | 0.65 (0.25)† |
| (7) Urban 2,500-19,999, not adj to metro | 0.57 (0.19)* | 0.55 (.25)* | 0.69 (0.26) |
| (8) Rural or <2,500, adjacent to metro | 0.78 (0.31) | 1.05 (0.30) | 1.19 (0.26) |
| (9) Rural or <2,500, not adj to metro | 0.70 (0.25) | 0.72 (0.47) | 0.94 (0.48) |
| **Socioeconomic Characteristics** | | | |
| Gini Coefficient 2000 | | 0.58 (1.86) | 1.43 (1.90) |
| Percent Black | | 1.03 (0.01)** | 1.03 (0.01)** |
| Percent Hispanic | | 1.00 (0.003) | 1.00 (0.004) |
| Economic Factor Score | | | 1.16 (0.06)* |
| **Social Capital Characteristics** | | | |
| Putnam Type Establishments | | | |
| Olsen Type Establishments | | | |
| **Social Environment Characteristics** | | | |
| Crime Factor Score | | | |
| **Health Services Characteristics** | | | |
| Health Services Factor Score | | | |
| Total Hospitals per 10,000 Population | | | |
| Level-I (Individual) Characteristics | | | |
| **Biological Characteristics** | | | |
| Child Sex (1=male) | 0.77 (0.08)* | 0.78 (0.08)* | 0.78 (0.08)* |
| Gestational age (weeks) | 0.61 (0.02)** | 0.61 (0.02)** | 0.61 (0.02)** |
| Twin (1=yes) | 9.54 (0.10)** | 9.84 (0.10)** | 9.81 (0.10)** |
| Maternal Complications | 1.84 (0.10)** | 1.86 (0.09)** | 1.86 (0.09)** |
| Newborn Conditions | 2.44 (0.14)** | 2.49 (0.14)** | 2.50 (0.14)** |
| **Social Characteristics** | | | |
| Mom High School (ref=less than HS) | 1.21 (0.13) | 1.22 (0.136) | 1.22 (0.13) |
| Mom College or More | 1.12 (0.14) | 1.13 (0.14) | 1.13 (0.15) |
| Income | 1.00 (0.000001) | 1.00 (0.000001) | 1.00 (0.000001) |
| Health Insurance (1=yes) | 1.04 (0.11) | 1.05 (0.11) | 1.06 (0.11) |
| Mother’s Age at Birth | 0.83 (0.05)** | 0.82 (0.05)** | 0.82 (0.05)** |
| Mother’s Age at Birth Squared | 1.00 (0.001)** | 1.00 (0.001)** | 1.00 (0.001)** |
| Black (reference=white) | 1.53 (0.14)* | 1.45 (0.14)* | 1.46 (0.14)* |
| Hispanic | 1.13 (0.12) | 1.16 (0.12) | 1.17 (0.12) |
| Asian | 1.62 (0.14)** | 1.62 (0.15)* | 1.73 (0.15)** |
| Other | 1.27 (0.25) | 1.32 (0.26) | 1.31 (0.26) |
| Married (1=yes) | 0.78 (0.10)* | 0.77 (0.10)* | 0.77 (0.10)* |
| **Behavioral Characteristics** | | | |
| Smoke while Pregnant | 2.03 (0.14)** | 2.08 (0.14)** | 2.11 (0.14)** |
| Drink while Pregnant | 1.64 (0.40) | 1.72 (0.38) | 1.75 (0.38) |
| Number Prenatal Visits | 1.00 (0.01) | 1.00 (0.01) | 1.00 (0.01) |
| Weight Gain | 0.68 (0.06)** | 0.68 (0.06)** | 0.68 (0.06)** |
| Food Secure (1=yes) | 1.03 (0.15) | 1.06 (0.15) | 1.06 (0.16) |
| Preg Not Wanted (ref=wanted preg) | 1.15 (0.15) | 1.16 (0.15) | 1.16 (0.15) |
| Pregnancy Not Sure | 0.92 (0.17) | 0.94 (0.17) | 0.94 (0.17) |
| WIC (1=yes) | 0.97 (0.11) | 0.97 (0.11) | 0.98 (0.11) |

** $p \leq .001$ * $p \leq .05$ † $\leq .10$

[a] Reference category for the rural-urban continuum codes is central counties of metro areas of 1 million population or more

between 2,500 and 19,999 residents not adjacent to a metro county are about half as likely to be low birth weight as infants born to mothers in the most metro county designation. All other counties using the rural-urban continuum codes have similar odds of having a low birth weight infant as residents of metro counties with a core urban population of one million or more residents.

Odds ratios for individual-level controls in this model are the same/consistent with those found in Chapter 3. All biological characteristics of the infants and mothers have significant relationships with the outcome variable. Twins are almost 10 times more likely to be born low birth weight compared to single birth infants. Black and Asian infants are much more likely to be low birth weight than white infants. No significant difference in birth weight status is observed between white infants and Hispanic and other or multiple race infants. Marriage is protective against low birth weight. A mother that smokes during her pregnancy is the main behavioral characteristics to increase the likelihood that an infant will be born low birth weight. These relationships stay the same when additional county-level characteristics are added in subsequent models.

Socioeconomic characteristics of counties are added in Models 2 and 3 in Table 4.10a. Having a large percentage of black residents in a county increases the likelihood that an infant will be born low birth weight by 1.03 times (coefficient= 0.027). If a county had a black population constituting twenty-five percent of the population, infants in that county would be 1.96 times more likely to be born low birth weight than infants in a county with no black residents. Relationships between the odds of having a low birth weight infant and rural-urban continuum codes remain the same with the addition of the Gini coefficient and racial composition measures in Model 2. No significant relationship is observed for the level of income inequality for an infant's county of residence and the likelihood that the infant will be born low birth weight.

A statistically significant positive relationship (coefficient = 1.16) exists between the economic factor score for the county and the likelihood that an infant will be low birth weight in Model 3. The addition of the economic factor score in this model also changes the relationship between some of the rural-urban continuum code designations and the outcome variable. Infants in nonmetro counties with an urban population between 2,500 and 19,999 not adjacent to a metro county do not have statistically different odds of being born low birth weight than infants in metro central cities with a population of one million or more. Odds ratios for county designations 5 and 6 become only marginally significant when this factor score is added in Model 3. Infants in metro counties with a population between 250,000 and one million are 1.77 times more likely to be low birth weight than infants in central metro counties with a population of one million or more. The odds ratio and significance level for the percentage of the county population that is black remains the same from Model 2 to Model 3.

When social capital characteristics are added in Model 4 in Table 4.10b, the economic factor score is no longer statistically significant. Infants born in a county with a larger number of Olsen-type establishments are more likely to be low birth weight compared to infants in counties with none of these establishments. The same likelihood of low birth weight is found in this model for infants born in counties with a high percentage of the county population that is black. Only two of the rural-urban continuum code designations remain statistically significant with the addition of social characteristics to the model. Infants in metro counties with a population between

250,000 and one million are still much more likely to be low birth weight compared to infants in core metro counties with a population of one million or more residents. Infants born in nonmetro counties with an urban population of 20,000 or more not adjacent to a metro county are half as likely to be low birth weight as infants born in the most metro county designation with a population of one million or more.

Measures of the social environment and health services for counties are added in Models 5 and 6 in Table 4.10b. While the crime factor score is not statistically significant in Model 5, the addition of this variable creates marginally significant relationships for rural-urban continuum code designations 6 and 7. Infants born in these counties are one-third as likely to be low birth weight as infants in core metro counties with one million or more residents. This may reflect lower crime rates, both property and violent crimes, in these types of nonmetro counties that is observed when the crime factor score is incorporated in Model 5. Not having to deal with stress associated with living in an area with high crime rates may be beneficial to the health of pregnant women and infants in certain nonmetro counties. Infants in metro counties with a population between 250,000 and one million continue to have higher odds of low birth weight than infants in core metro counties with a population of one million or more.

Health services characteristics, both a health services factor score and the total number of hospitals per 10,000 residents in a county, are significant in determining the likelihood of individual low birth weight status in Model 6. A positive relationship exists between the health services factor score and the odds of low birth weight status. Infants living in a county with a large number of hospitals for the county population are about

Table 4.10b: Random Intercept Models of Dichotomous Low Birth Weight Variable (1=yes) on County- and Individual-Level Characteristics, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Odds Ratio (Standard Error)

| | Model 4 | Model 5 | Model 6 |
|---|---|---|---|
| Intercept | 0.09 (0.11)** | 0.09 (0.11)** | 0.08 (0.11)** |
| Level-II (County Characteristics) | | | |
| **Residential Characteristics** | | | |
| (1) Metro fringe, 1million or more [a] | 0.76 (0.21) | 0.75 (0.21) | 0.83 (0.18) |
| (2) Metro, 250,000 – 1 million | 1.74 (0.17)** | 1.72 (0.17)* | 1.88 (0.15)** |
| (3) Metro, less than 250,000 | 1.00 (0.20) | 1.00 (0.20) | 1.08 (0.21) |
| (4) Urban 20,000+, adjacent to metro | 1.02 (0.23) | 1.01 (0.23) | 1.13 (0.25) |
| (5) Urban 20,000 +, not adj to metro | 0.48 (0.34)* | 0.74 (0.35)* | 0.55 (0.36) |
| (6) Urban 2,500-19,999, adj to metro | 0.66 (0.25) | 0.65 (0.25)† | 0.78 (0.23) |
| (7) Urban 2,500-19,999, not adj to metro | 0.66 (0.26) | 0.65 (0.25)† | 0.92 (0.25) |
| (8) Rural or <2,500, adjacent to metro | 0.94 (0.23) | 0.94 (0.23) | 1.45 (0.18)* |
| (9) Rural or <2,500, not adj to metro | 0.91 (0.50) | 0.89 (0.51) | 1.38 (0.52) |
| **Socioeconomic Characteristics** | | | |
| Gini Coefficient 2000 | 0.79 (1.96) | 0.76 (1.94) | 0.06 (2.03) |
| Percent Black | 1.03 (0.01)** | 1.03 (0.01)** | 1.03 (0.01)** |
| Percent Hispanic | 1.00 (0.01) | 1.00 (0.01) | 1.00 (0.005) |
| Economic Factor Score | 1.08 (0.07) | 1.08 (0.07) | 0.89 (0.08) |
| **Social Capital Characteristics** | | | |
| Putnam Type Establishments | 0.99 (0.02) | 0.99 (0.02) | 0.98 (0.02) |
| Olsen Type Establishments | 1.16 (0.05)* | 1.16 (0.05)* | 1.16 (0.04)** |
| **Social Environment Characteristics** | | | |
| Crime Factor Score | | 0.98 (0.05) | 0.95 (0.05) |
| **Health Services Characteristics** | | | |
| Health Services Factor Score | | | 1.35 (0.06)** |
| Total Hospitals per 10,000 Population | | | 0.26 (0.52)* |
| Level-I (Individual) Characteristics | | | |
| **Biological Characteristics** | | | |
| Child Sex (1=male) | 0.78 (0.08)* | 0.78 (0.09)* | 0.78 (0.08)* |
| Gestational age (weeks) | 0.61 (0.02)** | 0.61 (0.02)** | 0.60 (0.02)** |
| Twin (1=yes) | 9.85 (0.10)** | 9.86 (0.10)** | 10.01 (0.10)** |
| Maternal Complications | 1.85 (0.10)** | 1.86 (0.10)** | 1.85 (0.10)** |
| Newborn Conditions | 2.50 (0.14)** | 2.50 (0.14)** | 2.47 (0.14)** |
| **Social Characteristics** | | | |
| Mom High School (ref=less than HS) | 1.21 (0.13) | 1.21 (0.13) | 1.20 (0.13) |
| Mom College or More | 1.12 (0.15) | 1.12 (0.15) | 1.12 (0.15) |
| Income | 1.00 (0.000001) | 1.00 (0.000001) | 1.00 (0.000001) |
| Health Insurance (1=yes) | 1.05 (0.10) | 1.06 (0.11) | 1.05 (0.11) |
| Mother’s Age at Birth | 0.82 (0.05)** | 0.82 (0.05)** | 0.83 (0.05)** |
| Mother’s Age at Birth Squared | 1.00 (0.001)** | 1.00 (0.001)** | 1.00 (0.001)** |
| Black (reference=white) | 1.46 (0.14)* | 1.46 (0.14)* | 1.48 (0.14)* |
| Hispanic | 1.18 (0.12) | 1.18 (0.12) | 1.19 (0.12) |
| Asian | 1.74 (0.14)** | 1.73 (0.14)** | 1.74 (0.14)** |
| Other | 1.30 (0.26) | 1.29 (0.26) | 1.29 (0.26) |
| Married (1=yes) | 0.77 (0.10)* | 0.77 (0.10)* | 0.77 (0.10)* |
| **Behavioral Characteristics** | | | |
| Smoke while Pregnant | 2.15 (0.14)** | 2.15 (0.14)** | 2.18 (0.14)** |
| Drink while Pregnant | 1.76 (0.38) | 1.76 (0.38) | 1.66 (0.40) |
| Number Prenatal Visits | 1.00 (0.01) | 1.00 (0.01) | 1.00 (0.01) |
| Weight Gain | 0.68 (0.06)** | 0.68 (0.06)** | 0.67 (0.06)** |
| Food Secure (1=yes) | 1.07 (0.16) | 1.07 (0.16) | 1.07 (0.16) |
| Preg Not Wanted (ref=wanted preg) | 1.15 (0.15) | 1.15 (0.15) | 1.15 (0.15) |
| Pregnancy Not Sure | 0.94 (0.17) | 0.94 (0.17) | 0.94 (0.18) |
| WIC (1=yes) | 0.97 (0.11) | 0.97 (0.11) | 0.96 (0.11) |

** $p \leq .001$ * $p \leq .05$ † $\leq .10$

[a] Reference category for the rural-urban continuum codes is central counties of metro areas of 1 million population or more

one-fourth as likely to be low birth weight. With the inclusion of all county-level variables in Model 6, infants in nonmetro counties completely rural or with a population less than 2,500 adjacent to metro areas are 1.45 times more likely to be low birth weight than infants in core metro counties with a population of one million or more. This is the first time in this set of models that this designation has a statistically different odds ratio from the most metro county designations. Infants in county designation 2 continue to fare worse than their most metro counterparts. Of the remaining county-level characteristics, the racial composition and Olsen-type establishments are important for raising the odds that an infant will be low birth weight. All relationships between the individual-level covariates and the outcome variables remain the same in these six models.

**Other Residential Characteristics and Low Birth Weight Status**

Similar to models estimated above using the continuous measure of birth weight, models using the dichotomous measures of birth weight status are estimated with different measures of residential characteristics, including a dichotomous measure of metro/nonmetro county status, the percentage of the county population that is rural, and population density. Results from a one-way analysis of variance (ANOVA) test suggest that significant differences in low birth weight status exist between infants in metro and nonmetro counties. Table 4.11 presents results from this test. Six percent of infants in the sample weighted to all births in the population for 2001 living in nonmetro counties are likely to be born low birth weight, compared to eight percent of infants from metro counties.

Table 4.11. ANOVA for Dichotomous Dependent Variable of Low Birth Weight Status (1=yes) by Metro/Nonmetropolitan Status

| Metro/Nonmetropolitan Status | Mean | Standard Deviation | Number of Cases |
|---|---|---|---|
| *With Weighting* | | | |
| Metropolitan Counties | 0.08 | 0.29 | 8,155 |
| Nonmetropolitan Counties | 0.06 | 0.24 | 2,453 |
| *Average Odds Ratio for the Population of Births* | *0.07* | *0.26* | *10,608* |
| F=48.737, p<0.001 | | | |

Table 4.12 gives odds ratios for all county- and individual-level variables with the inclusion of a dichotomous measure of metro/nonmetro county of residence. Individual infants in metro counties are 1.53 times more likely to be low birth weight than infants in nonmetro counties. A statistically significant relationship is also observed between the economic factor score and odds of low birth weight when the dichotomous measure of metro/nonmetro residence is used in the full model compared to the rural-urban continuum codes presented in Table 4.10b.

All other variables maintain the same relationship with the odds of low birth weight status for infants as the full model in Table 4.10b. Living in a county with a high percentage of black residents increases the likelihood that an infant will be born low birth weight. Similar to results presented in previous models above, a larger number of Olsen-type establishments in a county increase the odds that an infant will be low birth weight. Relationships between health services characteristics and the odds of low birth weight remain the same in this model. However the variation found when using rural-urban continuum codes is lost when only a dichotomous measures of metro/nonmetro residence is used in Table 4.12. Further results from this table indicate that all infants in metro counties have a higher odds ratio for being low birth weight than results from the full model using rural-urban continuum codes.

Table 4.12: Random Intercept Model of Dichotomous Low Birth Weight Variable (1=yes) on County- and Individual-Level Characteristics with Dichotomous Measures of Metropolitan Status, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Odds Ratio (Standard Error)

| | Model 6 (Full Model) |
|---|---|
| Intercept | 0.06 (0.1)** |
| Level-II (County Characteristics) | |
| **Residential Characteristics** | |
| Metropolitan County Status (1=metro) | 1.53 (0.17)* |
| **Socioeconomic Characteristics** | |
| Gini Coefficient 2000 | 0.33 (2.16) |
| Percent Black | 1.02 (0.01)** |
| Percent Hispanic | 1.00 (0.01) |
| Economic Factor Score | 0.84 (0.09)* |
| **Social Capital Characteristics** | |
| Putnam Type Establishments | 0.99 (0.02) |
| Olsen Type Establishments | 1.17 (0.16)** |
| **Social Environment Characteristics** | |
| Crime Factor Score | 0.93 (0.05) |
| **Health Services Characteristics** | |
| Health Services Factor Score | 1.30 (0.07)** |
| Total Hospitals per 10,000 Population | 0.34 (0.50)* |
| Level-I (Individual) Characteristics | |
| **Biological Characteristics** | |
| Child Sex (1=male) | 0.77 (0.08)* |
| Gestational age (weeks) | 0.61 (0.02)** |
| Twin (1=yes) | 9.96 (0.10)** |
| Maternal Complications | 1.85 (0.10 )** |
| Newborn Conditions | 2.45 (0.14)** |
| **Social Characteristics** | |
| Mom High School (ref=less than HS) | 1.20 (0.13) |
| Mom College or More | 1.14 (0.15) |
| Income | 1.00 (0.000001) |
| Health Insurance (1=yes) | 1.07 (0.11) |
| Mother's Age at Birth | 0.82 (0.05)** |
| Mother's Age at Birth Squared | 1.00 (0.001)** |
| Black (reference=white) | 1.47 (0.14)* |
| Hispanic | 1.19 (0.12) |
| Asian | 1.89 (0.14)** |
| Other | 1.32 (0.26) |
| Married (1=yes) | 0.76 (0.10)* |
| **Behavioral Characteristics** | |
| Smoke while Pregnant | 2.16 (0.14)** |
| Drink while Pregnant | 1.65 (0.41) |
| Number Prenatal Visits | 1.00 (0.01) |
| Weight Gain | 0.68 (0.06)** |
| Food Secure (1=yes) | 1.06 (0.16) |
| Preg Not Wanted (ref=wanted preg) | 1.15 (0.15) |
| Pregnancy Not Sure | 0.94 (0.18) |
| WIC (1=yes) | 0.96 (0.11) |

-Table Continues-

** p <.001 * p <.05 † <.10

Results of the full logistic multilevel model with a measure of the percentage of the county population that is rural and population density for the county are found in

Table 4.13. These two measures are the final operationalization of residential characteristics at the county-level. Infants living in counties with a high percentage of the county population that is rural are less likely to be low birth weight than infants born in counties with no rural population. The coefficient for this variable has a value of -0.0165. If infants were born in a county with 25 percent of the population rural, they would be one-third less likely to be low birth weight than infants born in counties with no rural population. Population density is also significant in this model, with an odds ratio of 1.00. This variable was not significant in the models above using the continuous dependent variable. The coefficient for this variable indicates that as the population density in a county, measured as the county population per county land area per square kilometer, increases the odds that an infant will be born low birth weight increases. Other relationships with the odds of low birth weight hold in this model similar to the previous models in Tables 4.10b and 4.12.

Similar to results from the models using a continuous measure of birth weight for the dependent variable, results from these models using different measures of residential characteristics suggest that the odds of low birth weight for nonmetro infants differs based on the measure of rurality that is used in the model. Nonmetro infants fare better in the models presented in Tables 4.12 and 4.13. For example infants in metro counties are 1.53 times more likely to be born low birth weight than infants in nonmetro counties. Infants fare the best, according to these results, if they live in a county with a very high percentage of county population being rural (OR=0.98). The inclusion of other county-level characteristics does not mediate this relationship. Results from models using the dichotomous dependent variable indicate that nonmetro infants are on average less likely to be low birth weight, with controls for other county- and individual-level characteristics.

Table 4.13: Random Intercept Model of Dichotomous Low Birth Weight Variable (1=yes) on County- and Individual-Level Characteristics with Percent Rural Population and Population Density, Early Childhood Longitudinal Study – Birth Cohort; n=10,608
Odds Ratio (Standard Error)

| | Model 6 (Full Model) |
|---|---|
| Intercept | 0.08 (0.07)** |
| Level-II (County Characteristics) | |
| **Residential Characteristics** | |
| Percent of County Population Rural | 0.98 (0.01)* |
| Population Density | 1.00 (0.00004)** |
| **Socioeconomic Characteristics** | |
| Gini Coefficient 2000 | 1.29 (2.15) |
| Percent Black | 1.02 (0.01)** |
| Percent Hispanic | 0.99 (0.01) |
| Economic Factor Score | 0.81 (0.08)* |
| **Social Capital Characteristics** | |
| Putnam Type Establishments | 1.00 (0.02) |
| Olsen Type Establishments | 1.16 (0.05)* |
| **Social Environment Characteristics** | |
| Crime Factor Score | 0.92 (0.05) |
| **Health Services Characteristics** | |
| Health Services Factor Score | 1.28 (0.07)** |
| Total Hospitals per 10,000 Population | 0.36 (0.45)* |
| Level-I (Individual) Characteristics | |
| **Biological Characteristics** | |
| Child Sex (1=male) | 0.78 (0.08)* |
| Gestational age (weeks) | 0.60 (0.02)** |
| Twin (1=yes) | 10.02 (0.10)** |
| Maternal Complications | 1.84 (0.10)** |
| Newborn Conditions | 2.43 (0.14)** |
| **Social Characteristics** | |
| Mom High School (ref=less than HS) | 1.19 (0.13) |
| Mom College or More | 1.13 (0.14) |
| Income | 1.00 (0.000001) |
| Health Insurance (1=yes) | 1.07 (0.11) |
| Mother’s Age at Birth | 0.83 (0.05)** |
| Mother’s Age at Birth Squared | 1.00 (0.001)** |
| Black (reference=white) | 1.46 (0.14)* |
| Hispanic | 1.16 (0.12) |
| Asian | 1.62 (0.14)** |
| Other | 1.33 (0.27) |
| Married (1=yes) | 0.76 (0.10)* |
| **Behavioral Characteristics** | |
| Smoke while Pregnant | 2.18 (0.14)** |
| Drink while Pregnant | 1.67 (0.41) |
| Number Prenatal Visits | 1.00 (0.01) |
| Weight Gain | 0.67 (0.06)** |
| Food Secure (1=yes) | 1.07 (0.15) |
| Preg Not Wanted (ref=wanted preg) | 1.15 (0.15) |
| Pregnancy Not Sure | 0.94 (0.18) |
| WIC (1=yes) | 0.96 (0.12) |
| $R^2$ | |

** p ≤.001  * p ≤.05  † ≤.10

**Discussion**

This chapter examined the statistical relationship between individual- and structural-level characteristics and birth weight, both individual birth weights and the odds of low birth weight status using multilevel modeling techniques. Individual-level biological, social, and behavioral measures, as well as county-level measures of residential, socioeconomic, social capital, social environment, and health services characteristics were included in these models. Results from the two separate analyses for the two dependent variables reveal different relationships with county-level characteristics when controlling for individual-level covariates.

Results with the individual-level covariates in this chapter are quite comparable to results from the previous chapter, indicating that biological measures of the infant and mother are most important in determining variation in average individual birth weight as well as predicting the odds of low birth weight status of an infant. Smoking while pregnant, a behavioral characteristic of the mother, is one of the key behavioral indicators at the individual-level to lowering birth weights and increasing the likelihood that an infant will be low birth weight.

Three county-level variables emerge as important in determining average birth weights across counties and the odds of low birth weight status. As hypothesized in Chapter 2, these three structural-level variables make an independent contribution to individual birth weights and the odds of low birth weight status. First, one of the measures of social capital is important in determining birth weights. Olsen-type establishments lower average birth weights and increase the odds that an infant will be low birth weight if the infant lives in a county with a larger number of these establishments for the county population. Olsen-type establishments are business type associations and likely reflect the economic structure of metro areas and fewer cases of social interaction or support that may be found with establishments that are part of the Putnam-type measure. Second, racial composition matters for lower average birth weights and increasing the odds that an infant will be low birth weight. Having a high percentage of black residents in a county is detrimental to the birth weight of all infants in that county. It should be noted that minorities, particularly blacks and Asians, weigh less at birth and have a greater odds of being low birth weight than white infants. Tests for interactions between race/ethnicity at the individual-level and racial composition at the structural-level would lend useful insight into racial difference in birth weights. Finally, health services have an interesting relationship with birth weight. Just because there is a large concentration of specially trained medical personnel in a county does not lead to better health outcomes. In fact many people may move closer to hospitals or medical specialists because they have poor health and need more specialized care. It should also be noted that the measure of income inequality in this analysis, specifically the Gini coefficient at the county-level, does not have a statistically significant relationship with average birth weights or the odds of having a low birth weight infant once other structural-level measures are included in the models. Therefore measures of social capital, socioeconomic characteristics, and health services in the county may help to explain some of the variation in birth weights due to the distribution of economic inequality in the county and therefore the lack of infrastructure supporting services critical for maternal and infant health.

As for measures of rurality at the county-level in this analysis, several things emerge. Variation does exist based on the rural-urban continuum code designation of the infant's county of residence, and an independent relationship between rurality status and birth weight is observed. Specifically, infants in metro counties with a population between 250,000 and one million have lower average individual birth weights and a greater likelihood of being a low birth weight infant. Of the nonmetro county categories, infants in nonmetro counties completely rural or with a population less than 2,500 are 1.45 times more likely to be low birth weight than infants in core metro counties with a population of one million or more. Models incorporating measures of the percentage of the county population that is rural and county population density indicate that infants living in counties with a large rural population have higher average birth weights and lower odds of being low birth weight. Each of these measures of rurality offers a different picture into how rurality affects birth weight. These differences indicate that we still do not have a clear idea about variation in birth weight for rural and urban infants.

Overall results from this research indicate that little variation exists in average birth weight and low birth weight status as explained by structural-level characteristics. However, the independent relationships between many of the structural-level characteristics and birth weight deserve further theoretical and empirical examination. In order to examine the differences in infant health outcomes by rurality status and other structural-level characteristics, similar methods should examine infant mortality rates or common infant and childhood morbidity patterns. In addition, cross-level interactions may lend insight into how individual-level characteristics operate within certain spatial contexts. Results in this chapter support the need for structural-level measures to be included with individual measures in order to assess the relationships between individuals and space for individual infant health outcomes.

# Chapter 5

## Conclusions and Implications

Health conditions of infants in the United States have improved greatly in the past several decades. Yet the United States continues to lag behind many developed nations, particularly Western European nations, on the nation's infant mortality rate (Population Reference Bureau 2005). This difference may be attributable to the prevalence of low birth weight infants in the U.S. and variation in rates across regions in the United States, since low birth weight remains the foremost risk factor for infant mortality and other childhood morbidity patterns (Thompson et al. 2005). In order to help narrow this gap for early infant health outcomes, a better understanding of the risk factors associated with variation in birth weight is needed. This involves looking beyond traditional biological conditions of pregnant women and infants and addressing the various levels of risk that are associated with poor birth weight outcomes. Theoretically, risk factors for poor infant health from a social perspective include socioeconomic and behavioral practices at the individual-level, and income inequality, minority concentration, and environmental hazards at the structural-level. Making the connection between these two levels to determine individual differences in birth weight has been missing in the infant health literature.

The objective of this thesis was to explore factors associated with birth weight at individual- and structural-levels in order to assess a more theoretically and empirically comprehensive approach to understand the individual health status of infants based on these two distinct levels of risk. Birth weight was operationalized as two different dependent variables in this research, and these two measures were used in order to gauge how risk factors lead to variation in birth weights for individual infants as well as determine the likelihood that an infant would be born low birth weight. In order to address both individual- and structural-level factors in this thesis, two sets of analyses were performed. First, individual-level measures were explored as they relate to birth weight. This analysis involved a comprehensive set of biological, social, and behavioral characteristics of infants and their mothers based on a national sample of births occurring in 2001. Results in this analysis established relationships at the individual-level that would be held constant in the second set of analyses when structural-level characteristics were introduced.

Second, multilevel methods were used to estimate relationships at the structural-level, in this case the infant's county of residence, with controls for individual-level characteristics of the mothers and infants in the sample. Measures of residential, socioeconomic, social capital, social environment, and health services characteristics were used at the structural-level. These characteristics were used to test for independent relationships between structural-level measures and individual infant outcomes. Three distinct measures of residential characteristics were employed to capture variation in birth weight based on the level of rurality of the infant's county of residence. Key findings from this research are reviewed in this chapter. Implications of this research for health policy and directions for future research are also explored.

# Findings

## Biology and Social Conditions: The Relationship between Individual-Level Characteristics and Birth Weight

Chapter 3 utilized data from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B) private use files. This data set offers detailed birth certificate data for a nationally representative probability sample of children born during the 2001 calendar year. Interviews with parents of these infants at the time the child was nine months of age provided additional social and economic characteristics of the mothers in the sample. Measures from this data set were used to examine the relationship between individual-level characteristics of the infants and mothers and individual birth weights in the population and the probability of an infant being low birth weight. Results from this analysis contribute to the infant health literature examining individual-level relationships by exploring in detail race-, sex-, and plurality-specific models.

A consistent finding to emerge in this chapter in all of the models using both the continuous and dichotomous dependent variables is that biological characteristics of mothers and infants are the most important individual-level characteristics for determining birth weights for individual infants or the probability that an infant will be low birth weight. Gestational age in weeks accounts for most of the variation in birth weight and low birth weight status. Infants born prematurely weigh much less than full term infants, and premature infants are much more likely to be low birth weight than infants carried to term. This finding is as expected based on results from previous research (Allen, Donohue and Dusman 1993; Hack and Fanaroff 1999; Hack, Friedman and Fanaroff 1996; Petrou 2005). Findings for the plurality status of the birth and sex of the infant are consistent with previous research (Blondel et al. 2002; Cohen et al. 1999; Martin and Park 1999; Ricketts, Murray and Schwalberg 2005). Twins tend to weigh less at birth and are more likely to be born low birth weight, while male infants weigh more at birth and are less likely to be born low birth weight. Maternal health complications during pregnancy and abnormal health conditions of the infant at birth lead to lower birth weight and increase the odds that an infant will be low birth weight. These results are as expected.

Results from the social characteristics included in the full models do not show support for the absolute-income hypothesis. Maternal educational levels and household income do not have statistically significant relationships with the outcome variables in the full models. Further research examining this hypothesis as it relates to infant health, particularly birth weight, is needed since the socioeconomic characteristics of mothers or households may not be directly transferred to the infant or socioeconomic status operates through behavioral factors. The relationship established in the absolute-income hypothesis deserves more consideration for infant health outcomes. The race/ethnicity of the infant does lead to important differences in individual birth weight and the odds of low birth weight status. On average, black infants, Asian infants, and infants of other or multiple races weigh less at birth than white infants. Hispanic infants do not have birth weights that are significantly different than white infants. This finding is supported by previous research. Black and Asian infants have higher odds of being born low birth weight than white infants, but no statistically significant difference in the odds of low birth weight status is found between white, Hispanic, and other or multiple race infants.

Tests for differences across the racial/ethnic groups were conducted, and these results indicate that not all biological, social, and behavioral characteristics operate the same for all racial groups in determining individual birth weights or the odds of low birth weight status. Compared to white and black infants, Hispanics infants benefit from higher household incomes. Infants of other and multiple races also have higher birth weight compared to Hispanics if the infant's mother has completed a high school education. Therefore, income and maternal educational levels for Hispanics and those of other or multiple races, respectively, confer more of a health advantage for their infants than infants of other races/ethnicities. As for low birth weight status, mothers completing a high school education decrease the odds that an Asian infant will be low birth weight compared to Hispanics. A mother being married while she is pregnant is protective against low birth weight status for white, black, and Hispanic infants compared to Asian and other or multiple race infants. These findings give new insights into the relationship between birth weight and race/ethnicity of the infants, but these relationships deserve further exploration.

Behavioral characteristics of the mother while pregnant were the final set of measures analyzed in this chapter. Maternal smoking behavior while pregnant was the main behavioral characteristics to be statistically significant in determining individual birth weights and the odds of low birth weight. Mothers who smoked during their pregnancy have infants that weight less at birth than mothers that do not smoke, and the odds of having a low birth weight infant increase greatly if the mother smokes during the pregnancy. Both the number of prenatal visits the mother attends and gaining at least twenty-five pounds during pregnancy have positive significant relationships with individual birth weights. WIC usage during pregnancy lowers the likelihood that an infant will be low birth weight. No statistically significant differences based on race/ethnicity are observed for this relationship when race-specific models are examined. Therefore this finding could have important policy implications for low income mothers of all races and the health status of their infants at birth.

Results for these three sets of characteristics, biological, social, and behavioral, on birth weight are consistent with previous research examining individual-level relationships. However, differences and variation still remain in determining individual birth weight and the odds of low birth weight status based on biological, social, and behavioral characteristics of mothers and infants. Suggestions about how to better understand these differences are presented below as directions for future research.

### Rurality, Income Inequality, and Contextual Effects: Implications for Birth Weight Using Multilevel Methods

In Chapter 4, multilevel modeling techniques were used to assess the relationship between structural-level measures with controls for individual-level covariates on both average birth weights in the population and the odds of low birth weight status. Secondary data sources aggregated to the county-level used for this analysis include Economic Research Service Rural-Urban Continuum Codes; 2000 U.S. Census of Population and Housing, Summary File 3 (SF3); 2000 County Business Patterns; 2000 Uniform Crime Reports; and the 2004 Area Resource Files. County geographical identifiers contained on the infant' birth certificate in the ECLS-B allowed the secondary data sources to be merged with the individual-level characteristics of the infants and mothers. This merged data file offers an innovative and current data set to examine birth weight outcomes using multilevel methods of analysis.

Individual-level relationships established in Chapter 3 were held constant for analyses in Chapter 4 in order to gauge the independent relationships between structural-level characteristics and birth weights and the odds of low birth weight status for individual infants. Five categories of structural-level characteristics were considered in analyses from Chapter 4. These include residential, socioeconomic, social capital, social environment, and health services characteristics of the infant's county of residence. To test for variability in the outcome based on the rurality status of the infant's county of residence, three sets of residential measures were employed. First, models were estimated using rural-urban continuum codes which incorporate measures of population size and adjacency into the coding scheme. Full models were then estimated using a dichotomous measure of the county's metro/nonmetro status. The percentage of the county's population that is rural and population density for the county were used as the third set of residential characteristics. These different measures of rurality help to capture the impact that structural-level conceptualizations of population distribution and density have in offering explanations for variation in infant health outcomes. Interesting findings emerge with these three different operationalizations of rurality. Results from analyses in Chapter 4 offer new insight into how average birth weights and the odds of low birth weight status of individual infants differ when individual- and structural-level measures are considered simultaneously. Additionally these results raise questions about differences in average birth weights and the odds of low birth weight status for nonmetro residents.

When examining average birth weights with only rural-urban continuum codes and controls for individual-level covariates in the model, a great deal of variation is found between the various county designations. Five of the six nonmetro county designations have infants with higher average birth weights than infants in core metro counties with a population of one million or more. One the other hand, infants in metro counties with a population between 250,000 and one million have average birth weights that are lower than infants in the most metro county designation. This relationship is the only relationship among the rural-urban continuum codes to remain with the inclusion of all structural (county-level) measures. A similar pattern exists for predicting the odds of low birth weight status. However, with the inclusion of all structural level variables, infants in metro counties with a population between 250,000 and one million and infants in nonmetro counties completely rural or with an urban population less than 2,500 adjacent to metro counties have odds of being low birth weight that are higher than infants in core metro counties with a population of one million or more. The addition of other structural-level measures may account for the loss of variation that is initially observed from nonmetro residence, indicating that these other measures capture the characteristics of nonmetro counties that make the health of their infants different from infants in the most metro county designation.

The percentage of the county population composed of black residents is important in models using both the continuous and dichotomous dependent variable. As the percentage of black residents in a county increases, average birth weights in those counties are lower. Likewise the odds of having a low birth weight infant are greater in counties with a larger percentage of black residents. It should be noted that the relationship between black infants and average birth weights and the odds of low birth weight status found in Chapter 3 also hold in analyses in this chapter with the addition of structural-level characteristics.

Another interesting finding to emerge from this chapter is the relationship between the number of Olsen-type establishments in the county and the two outcomes of interest. Infants born in counties with a larger number of Olsen-type establishments per 10,000 residents in the county will have lower birth weights on average than infants born in a county with none of these establishments. Having a larger number of Olsen-type establishments for the county's population also increases the odds that an infant in that county will be low birth weight. This may be due to the nature of Olsen-type establishments, which are business oriented and may reflect some of the disadvantage of living in a metro area on birth weight. It is surprising that no significant relationship is found for Putnam-type establishments and birth weight, as participation in these types of activities may prevent engaging in negative behaviors, such as smoking while pregnant and is likely to provide social support to pregnant women and their infants. Relationships with health services characteristics and birth weight are somewhat counterintuitive but not too surprising. Living in an area with a high concentration of medical specialists lowers average birth weights and increases the odds that an infant will be low birth weight. This may largely reflect the movement of women with health complications during pregnancy to places with a concentration of medical specialists in order to seek medical care to prevent negative birth outcomes.

Differences in average birth weights and the odds of low birth weight status are observed when various measures of rurality are used in this analysis. Models using a dichotomous measure of metro/nonmetro status reveal that infants in metro counties weigh less at birth on average than infants in nonmetro counties. This result masks variation in birth weights that is found within types of metro counties when the rural-urban continuum codes are used. When the percentage of the county population that is rural and population density are used as measures of residential characteristics, results from the full model indicate that infants living in a county with a higher percentage of the county population rural weigh more at birth on average than infants born in a county with no rural population. Similar results are found for determining the odds of low birth weight status. Infants in metro counties are more likely to be low birth weight than infants in nonmetro counties, and living in a county with a higher percentage of the population rural lowers an infant's odds that they will be low birth weight. Most interesting across these models is that the results for nonmetro residents remain with the inclusion of other county-level characteristics. Therefore, something about population size may be more important in trying to explain the variation found in birth weight. Results from this chapter contribute to the growing literature using theories involving multiple levels of influence and analytic strategies to account for variation in infant health outcomes. Results from this chapter indicate/suggest many ideas for future research.

## Theoretical Implications

Several important theoretical implications can be taken from this work. Results from Chapter 3 find strong support for relationships between individual-level characteristics and birth weight and the odds of low birth weight status for individual infants. Relationships for biological characteristics in this model support the empirical findings of small clinical based studies and larger national studies of birth weight. More research focusing on genetic correlates of low birth weight may be useful for future research that explores birth weight differentials among individual infants. However, theoretical arguments linking genetic variation and social characteristics for infant health outcomes are needed.

While much support exists for the absolute-income hypotheses in studies of adult health outcomes, results from Chapter 3 do not find support for this hypothesis for infant health outcomes, and more specifically birth weight. Only a few studies have addressed this hypothesis as it relates to infant health outcomes, and these studies have only tested the relationship indirectly (Conley and Bennett 2000, 2002). Finch (2003a) argues that the social positioning of individuals may take a period of time to manifest and therefore relationships between measures of socioeconomic status and health may not be observed until adolescence or adulthood. Many more studies are needed to test to see if socioeconomic characteristics of pregnant mothers are transferred to their infants, leading to health differentials based on socioeconomic status or if this relationship operates through other behaviors. Other measures of socioeconomic status, such as a composite score based on the mother's education, income, and occupation may yield different results. Results from this research indicate that the health-SES relationship for infants needs further investigation and more conceptualization around the transfer of socioeconomic traits from mothers to infants and how that occurs, directly or indirectly through behavior.

Racial/ethnicity differences found in Chapter 3 also raise questions about the need for theories of infant health to account for variation in individual birth weight and the odds of low birth weight status for certain racial groups. Attention may need to be directed to biological, social, and cultural differences attributable to members of various racial and ethnicity groups. For example, if not all racial groups are at risk of having health complications while pregnant or engaging in risk behaviors, such as smoking cigarettes or consuming alcohol while pregnant, different models should be devised to account for this variation in order to assess variation in individual birth weight and low birth weight status.

Another important relationship found in Chapter 3 is between the age of the mother at the time of birth and birth weight. When a squared term of the mother's age is incorporated into the models, an inverse U-relationship is found. Therefore mothers experience good infant health outcomes until a certain age and then this advantage begins to deteriorate. A similar pattern is generally found for infant mortality patterns, but less work on this topic has been devoted to birth weight. A more refined way of measuring advantages and disadvantage of maternal age with birth weight would be useful for future studies.

Results from Chapter 4 make an interesting contribution to the theoretical literature linking structural-level characteristics to individual infant health outcomes. Most studies examining infant health outcomes give few explanations as to why structural-level measures are likely to influence individual infant health outcomes or how these characteristics may have independent relationships with birth weight risks. One important relationship examined from this perspective is between the level of rurality of the infant's county of residence and birth weight. Rural-urban continuum codes offer insight into the economic and social structure of nonmetro counties because the incorporation of adjacency in this measure offers insight into the commuting patterns for employment, income distributions, and the transfer/access to goods and services across space. Models incorporating other measures of adjacency and population size may be more useful for understanding the variation in birth weight. When these codes are used in the multilevel models, a consistent finding that infants in metro counties with a population between 250,000 and one million do worse than infants in core metro counties with a population of one million or more is found. Other measures of rurality, such as the metro/nonmetro designations of an infant's county of residence as well as the percentage of county residents that are rural and a measure of population density for the county, reveal fairly similar results in regard to average birth weight and the odds of low birth weight status.

How living in a rural place and the structure of economic, employment, social, and medical services in counties causes differential health outcomes for individual infants needs further exploration. Still a better understanding as to why this difference remains with the inclusion of all individual- and structural-level variables is needed for these designations of rural places to be useful for informing rural health policy. Results from this chapter largely indicate that the choice of measures used to capture the rurality status of the infant's county of residence will lead to different results, and a more consistent theoretical construct of rurality may make studies of infant health and policy recommendations more consistent.

An important argument from this chapter can also be made for a more comprehensive theoretical examination of a variety of individual infant health outcomes, including mortality and morbidity patterns, and structural-level characteristics. Special attention should be given to the impact of spatial inequality at the aggregate level on individual measures of infant health. To date, theory has focused on structural level characteristics and aggregate measures of health or individual adult health risks. More theoretical development with respect to infant health risks could offer better explanations into the variation that exists in individual health outcomes at the structural level. A more comprehensive theoretical approach capturing the impact of place on infant and child health risks would also be useful for the integration of infant, adolescent, and adult health outcomes for studying life course perspectives on health based on multiple levels of risk.

## Health Policy Implications

Results of this research indicate, while important, biological characteristics of mothers and infants do not account for all of the variability in birth weight or the odds of low birth weight status. Four of the behavioral characteristics at the individual-level have important health policy implications. First, the relationship between mothers' smoking while pregnant and lower individual birth weight and higher odds of low birth weight status is well supported by this research. Programs to educate women about the harmful consequences of smoking during pregnancy may help to eliminate some of the variation in birth weight and low birth weight status among individual infants. This is the one modifiable behavioral characteristic that could lead to major reductions in the number of low birth weight infants in the United States.

The number of prenatal visits a woman receives is also very important to having a normal weight infant. If the costs associated with prenatal care are too high and therefore prevent women from seeking this type of care, policy should aim to reduce the costs of prenatal care and consider making the services means tested for mothers that do not have the economic resources to pay for the services. Distances to services and lost wages due to time off from work may also be seen as costs to prenatal care. Therefore prenatal care programs may need to be part of a mobile care unit that could come to pregnant women to help offset some of the costs to the women associated with this care. Prenatal care education could also be implemented as a part of general medical training so that pregnant women without access to specialized care would be able to receive prenatal care education while visiting a general medical doctor for other health concerns. Basic education on prenatal care should also be distributed more widely. This could include a social service agency providing written and audio material that could be mailed to women if they want to learn more about proper prenatal care but cannot attend prenatal care visits due to costs mentioned above.

An important part of prenatal care should be devoted to issues concerning nutritional intake during pregnancy. Healthy weight gain during pregnancy was found to contribute to better health outcomes for infants. Information about the proper foods to eat, nutritional supplements, and exercise during pregnancy can help women achieve a healthy weight gain during pregnancy. Health state departments could print brochures with this information and make them available in grocery stores so that pregnant women and other members of their family can engage in healthy nutritional practices while pregnant.

A final policy implication based on the behavioral characteristics of pregnant women is based on the relationship between WIC usage and lower odds of having a low birth weight infant. The supplemental Women, Infants, and Children program should be made available to all pregnant women. More outreach needs to occur in order to connect with all low income women, since results from this research indicate that the use of the program leads to better infant health outcomes. Surveillance programs at the county level could help to identify women that could take advantage of these services. This could be particularly important for women in nonmetro counties that may not have easy access to WIC offices or be aware of the services that are provided with this program. Employees of WIC could go out into the county to talk with eligible women about the program and increase participation. Increased usage of WIC could really help to lower the rate of low birth weight infants among low income pregnant women.

It is a bit harder to make policy recommendations based on the county-level characteristics used in Chapter 4. However, health care personnel in counties could be more aware of the economic, social, and demographic compositions of the counties they serve in order to offer more specialized advice to the population of pregnant women in those counties. Economically depressed counties may not have the infrastructure to support social services that would be beneficial for pregnant women in the county. In this case local health departments must seek funding for a wider distribution of educational resources focusing on such things are prenatal care and nutrition. Further mobile infant and pregnancy health units may be a viable usage of health service dollars for counties that have sparse, dispersed populations without access to specialized infant and maternal health. Additionally, some way of offering education about health and social service programs in nearby areas may help compensate for the absence of these services in local areas.

Targeted health policies to counties with poor birth weight and infant health outcomes are another option. If counties are identified as having poor services and infrastructures to allow pregnant women to receive prenatal care and access to a proper diet while pregnant, very specific programs for individual women and their children may help to eliminate some disparities in the most resource poor counties in the U.S.

## Directions for Future Research

Future research on variation in birth weight is necessary in the United States in order to have a better understanding about how early childhood conditions influence health outcomes later in the life course. Two separate lines of inquiry are suggested for future research based on analyses in this thesis. These include tests for interaction effects at both the individual- and structural-levels, race-specific multilevel models, and longitudinal analysis of early childhood health and development with subsequent waves of the ECLS-B. These steps for future research are detailed below.

Much of the variation in individual birth weights and the odds of low birth weight status is left unexplained with the inclusion of individual- and structural-level measures used in this study. Cross-level interactions would be useful for results presented in Chapter 4. Tests for interactions between racial-group at the individual-level and minority concentration at the structural-level would offer more insight into the mechanisms by which variation in birth weight is based not only on an individual's race/ethnicity but also on the racial composition of the places people live. Interactions between SES measures at the individual-level and measures of rurality at the contextual-level may offer better insight into how the economic structure of nonmetro areas operate on individual-level measures of SES to influence birth weight risks. Since differences in birth weights based on race/ethnicity were observed when estimating individual race-specific models, similar models should be tested using multilevel models.

Once subsequent waves of the ECLS-B become available, the use of longitudinal methods would be useful in understanding how birth weight influences childhood morbidity patterns and developmental outcomes. Infants from the ECLS-B sample will be followed until the age of 6, so models similar to the ones in this thesis would be a good starting point for estimating early childhood morbidity and developmental outcomes. This type of research is missing from the infant and child health literature. A better understanding of the way individual-level social and behavioral characteristics of families and structural-level economic and social characteristics, with the incorporation of low birth weight status as an individual-level variable, would offer much more insight into the study of childhood health conditions which could have important implications for health later in the life course.

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# Appendix A

## Taylor Series and Jackknife Estimation Techniques

Both Taylor Series and jackknife estimation techniques have the ability to estimate standard errors based on the sampling design of the ECLS-B when using statistical software such as SAS, STATA, or AM. Taylor series and jackknife estimation are exact methods used to calculate standard errors and are preferred over approximation methods involving normalized or DEFF weights for this data set (U.S. Department of Education 2005).

Taylor series estimation is a method for obtaining robust variance estimators for complex survey data with stratified, cluster sampling with unequal probabilities of selection. The Taylor series method is used to obtain an approximation to some nonlinear function, and then the variance of the function is based on the Taylor series approximation to the function. This general computational procedure can be applied to a variety of nonlinear estimators such as regression coefficients (Binder 1983; Godambe and Thompson 1986). In a complex survey design such as the ECLS-B, this method of approximation is applied to the PSU totals within the stratum.

Jackknife repeated replication (JRR) is a method to estimate the sampling variability of a statistic that takes into account the properties of the sample design. It provides unbiased estimates of the sampling error arising from complex sample selection procedures; reflects the component of sampling error introduced by the use of weighting factors that are dependent on the sample data obtained; and can be readily adapted to the estimation of sampling errors for parameters estimated using statistical modeling procedures. The general idea behind the Jackknife is to split a single sample into multiple subsamples and use the fluctuation among the subsamples to obtain an estimate of the overall sampling variability. The first step in this procedure is to divide the full sample into random groups. In turn, each group is removed from the full sample in order to create a subsample. The JRR procedure derives estimates of the parameter of interest from each of the subsamples, and calculates the variance of the full-sample estimate from the variability between the subsample estimates (Lee, Forthofer and Lorimor 1989; Särndal, Swensson and Wretman 1992).

# Appendix B

## Combining of Counties from the Early Childhood Longitudinal Study – Birth Cohort

The sampling framework used in the ECLS-B was designed to allow for maximum, efficient coverage of the target population while keeping data collection costs down. Births were sampled within a set of primary sampling units that were made up of counties. Some counties in this data set only had a few births sampled, ranging from 5 to 12 infants. In order to use multilevel modeling techniques in Chapter 4 of this thesis, counties with a small number of cases had to be combined with surrounding counties. Counties with few cases were combined with adjacent counties with a larger sample of infants. In order to maintain the county characteristics of the infant's county of residence, proportional values based on the total number of individuals sampled in each of the counties being combined were used to construct the county-level variables in this analysis. All individual-level variables have the same values as reported in the ECLS-B. The rural-urban continuum code categories for each of the counties were also taken into consideration in order to maintain the nonmetro counties in this analysis. With the counties combines, there are a total of 176 counties at level-II for the analysis in Chapter 4.

**Curriculum Vita**

**Patrice Johnelle Smith**

**Education**

Ph.D. The Pennsylvania State University, Rural Sociology and Demography, 2006
M.A. University of Sydney, Australia, Social Policy, 2003
M.A. University of Arkansas, Sociology, 2003
B.A. University of Arkansas, Sociology and Criminal Justice, 2001

**Professional Employment**

Assistant Professor, Department of Demography and Organization Studies, University of Texas at San Antonio, 2006-present.
Graduate Research Assistant, Department of Agricultural Economics and Rural Sociology, The Pennsylvania State University, 2003-2006.
Graduate Research Assistant, Department of Human Development, Family Sciences and Rural Sociology, University of Arkansas, 2001-2003.

**Selected Publications**

McLaughlin, Diane K., C. Shannon Stokes, P. Johnelle Smith, and Atsuko Nonoyama. 2006 “Differential Mortality in the U.S.: An Intersection of Space and Place.” *Spaces, Places, and Inequality: The Sociology of Spatial Inequality*. State University of New York Press.
Durham, Rachel E. and P. Johnelle Smith. Forthcoming “Nonmetropolitan Status and Kindergarteners’ Early Literacy Skills: Is There A Rural Disadvantage?” *Rural Sociology*

**Grants and Fellowships**

Rural Sociological Society Dissertation Grant, 2005-2006, ($3,750)
Rotary International Ambassadorial Fellowship, 2002-2003, ($25,000)

**Selected Awards and Honors**

Kenneth P. Wilkinson Memorial Scholarship in Rural Sociology
Thomas C. and Jackie M. Floore Memorial Scholarship Fund in Agricultural Economics and Rural Sociology
Rural Sociological Society Student Paper Award
Ruth Pretty Palmer Scholarship, Alpha Delta Pi Foundation, Inc.

**Selected Presentations**

Smith, P. Johnelle. 2006. “Inequality and Infant Health: A Multilevel Approach to Disentangling Correlates of Metropolitan/Nonmetropolitan Disparities in Low Birth Weight Infants.” At the Annual Meeting of the Population Association of America, Los Angeles.
Durham, Rachel E. and P. Johnelle Smith. 2005. “Nonmetropolitan Status and Kindergarteners’ Early Literacy Skills: Is There a Rural Disadvantage?” At the Annual Meeting of the Population Association of America, Philadelphia.