Inequality and Infant Health: A Multilevel Approach to Disentangling Correlates of Metropolitan/Nonmetropolitan Disparities in Low Birth Weight Infants

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Abstract

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To date, research has not addressed geographic differentials in birth weight status 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. Prior research focusing on rural and urban differences in birth weight has mostly used dichotomous measures of residence. This proposed research utilizes multiple levels of rurality as one component of structural-level characteristics, along with individual-level characteristics, to estimate average birth weights and the odds of low birth weight status. With variation in birth weight status 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 will be used to examine this problem.

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Introduction

A complex set of individual- and structural-level characteristics influence overall birth weight, and a different set of risks are associated with birth weight at these two separate levels of aggregation. To date, research has not adequately addressed geographic differentials in overall birth weight or low birth weight status due to differences in individual- and structural-level characteristics in the United States. If the health care needs of infants and children in the US are to be understood, an analytic approach capturing how both individual- and local structural-level inequalities operate is needed. Prior research focusing on rural and urban differences in low birth weight 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 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 individual-level risk factors and geographic differentials at the structural-level contribute to poor infant health. This research utilizes multiple levels of rurality as one component of structural-level characteristics, along with individual-level biological, social, and behavioral characteristics, to determine overall birth weight and predict the likelihood of low birth weight status.

Theoretical Framework – Inequality and Stratification in Health

When studying health outcomes, it is necessary to understand the contexts in which individuals operate and how these contexts put individuals at different levels of risk. Inequality and stratification at the individual and structural levels have been shown to lead to differential infant health outcomes. Incorporating these two levels in order to examine geographic differentials in birth weights involves understanding two key components of inequality. First are the individual-level risk factors often researched in the pediatric literature focusing largely on biological and behavioral mechanisms. Second is examining sociological and public health research at the structural-level to see how aggregate level inequality influences individual infant health outcomes. Difficulty emerges when connecting these two distinct levels of risk in order to capture the structure of places and how these structural-level characteristics would influence the health of individuals in specific geographical location.

Individual-Level Characteristics and Infant Health Outcomes

At the individual level, three distinct sets of characteristics emerge as important in determining overall birth weight and predicting low birth weight status. These include biological, social, and behavioral characteristics. Traditionally, biological measures have tended to account for most of the variation in overall birth weights and low birth weight status. Without taking account of biological measures, effects of other individual- and contextual-level measures will be biased. However social and behavioral characteristics can impact many of the biological processes and their relationships with birth weight.

Biological Characteristics

Gender is one of the key biological characteristics included in studies on birth weight and infant mortality. 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 low birth weight status.

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 gestations. Overall low birth weight premature infants have higher risks of infant mortality and other infant and childhood morbidity patterns (Vohr et al. 2000).

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 weights 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). Therefore infants from multiple births are at a higher risk of having lower overall birth weights and a greater likelihood of being born low birth weight compared to singleton birth infants.

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). Similarly abnormal health conditions of the infant can develop in urtero 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.

Social Characteristics

Inequality, manifest in many forms, has been shown to have a negative impact on 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. 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 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.

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). 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 (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).

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). However 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. 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: Chomitz et al. 1995; Hughes and Simpson 1995; Kramer 1987). 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.

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 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). 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, a U-shaped relationship is usually observed. This relationship usually disappears with the inclusion of sociodemographic variables (Kallan 1993).

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). These studies indicate that blacks are much more likely to have low birth weight infants even with SES and other individual factors controlled.

Marital status, a measure of family structure and social support, is an important social characteristics also mentioned in the infant health literature. The relationship between marital status and overall 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 (1997) 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. 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.

Behavioral Characteristics

The smoking behavior of pregnant women has been found to have one of the strongest relationships with low birth weight status and other infant health complications (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 less 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 et al. 1995; Day and Richardson 1991; Larroque 1992; Shiono and Behrman 1995).

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.

Access to fresh food prior 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). 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).

Much debate exists over the relationship between pregnancy wantedness and overall birth weight and low birth weight status (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). 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.

To better understand birth weights, it is essential to understand the relationship between income inequality at the structural-level and poor infant health outcomes at the individual-level. Theories incorporating the relative positioning of individuals within social and spatial contexts begin to address this concern, and theoretical explanations for these relationships are detailed next.

Structural-Level Characteristics and Infant Health Outcomes

Previous research has found a relationship between infant health and contextual-level characteristics (Brooks 1980; Gorman 1999; LaVeist 1989; Lillie-Burton and LaVeist 1996). In discussing structural-level characteristics, it is important to situate individuals 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, but 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).

Economic Characteristics

The relative-income hypothesis, an extension of the absolute-income hypothesis presented above, 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 1997). It is 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).

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). The systematic underinvestment in infrastructures systems could impose a material dimension on the inequality-health link for the poor and working class individuals in the United States. 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).

Economic 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. 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). If economic circumstances of a particular area prevent women from seeking out prenatal care or health services due to expenses or access restrictions, than the risk of having a low birth weight infant is likely to increase.

Residential Characteristics

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, which are not observed when just comparing metro and nonmetro counties. If differences between metro and nonmetro infant health outcomes are to be understood, a similar measure must be employed. 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). Using Rural-Urban Continuum Codes that incorporate the idea of adjacency will allow for a more thorough understanding of the diversity in birth weights that exists in nonmetro counties. This type of measure also allows for a better understanding of access, isolation, and low density issues that are common to nonmetropolitan areas.

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, the transferal 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. Using a more crude dichotomous measure of county designations may mask the variation that exits for birth weight in the more isolated nonmetropolitan counties.

Residents of rural areas may be at a disadvantage over and above more traditional measures of income inequality if they do not have access 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 (Hayward, Pienta, and McLaughlin 1997). This may be due to specific prenatal and early childhood health services not being available for a small and isolation 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.

Researchers are beginning to investigate the way in which the concentration of minorities exert 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. 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 (Colclaugh 1990). This underinvestment then translates into low wages and fewer quality employment opportunities (Zekeri 1997). If individual women in these areas, minorities and non-minorities alike, cannot see opportunities to benefit from the economic structure in place they are less likely to invest in their own health and the health of their infant.

Social Capital Characteristics

In the past several years, there has been an interest in public health research to examine the relationship between social capital and health outcomes (Kawachi, Kennedy, and Glass 1999; Lochner, Kawachi, and Kennedy 1999; Lomas 1998; Rose 2000; Veenstra 2000). A recent article by Carpiano (2006) argues that social capital is an important structural-level characteristics influencing health by offering 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.

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 can influence women’s behavior while pregnant (Sampson, Raudenbush and Earls 1997). 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).

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. Without an understanding of the importance of prenatal care for better infant health outcomes, many women may never seek out such services.

Data and Methods

Individual-level data are taken from the Early Childhood Longitudinal Study – Birth Cohort (ECLS-B). 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. Data collected in the first wave (infant nine months of age) include batteries of questions taken from birth certificates, the infants themselves including 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 data file from the ECLS-B and contains sensitive information about infants and their parents.

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 from the ECLS-B were then merged with other secondary data sources aggregated to the county-level to provide economic, residential, social capital, social environment, and health services measures to be used as level-II variables for this multilevel analysis. State and county codes were available for all infants in the sample except for eighty individual cases. These eighty cases were eliminated from the final sample in this analysis leaving 10,608 infants, because no geographical identifiers were available for these cases to be merged with other county-level variables.

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 US 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 variables used in this analysis from these various resources are detailed below.

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 will be used to indicate how structural-level variables raise or lower birth weights, with controls for individual-level covariates. 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.

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. **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 include the risk factors included on the infant's birth certificate[1]. These measures were combined into one variable capturing the mother's health risk factors during pregnancy (U.S. Department of Education 2005). Abnormal health conditions of infants at birth are also based on a variety of health problems listed on the infant's birth certificate and are combined to make a measure of **newborn health conditions**[2].

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. **Income** is measured as household income from all sources. The ECLS-B reports this variable as a composite measure with thirteen economic categories[3]. Since this categorization scheme does not accurately reflect

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[1] Maternal health complications included on the infant's birth certificate include: 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

[2] Abnormal conditions of the infant are reported on the birth certificate and include the following conditions: anemia hct less than 39/hgb 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

[3] 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.

differences in income from category 1 to category 13, midpoints of each category are used as a 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 as state or local government program or community based program.

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. **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 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. Whites serve 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.

Smoking and **drinking** behaviors during pregnancy are reported on this infant's birth certificate. Both are dichotomous measures for whether the mother smoked cigarettes or consumed alcohol during her pregnancy. The total **number of prenatal visits** the mother received during her pregnancy, a continuous measure, is also reported on the infant's birth certificate. **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). 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 between thirty-five and forty pounds is assigned a two.

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 these responses. The final individual-level 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 measure coded 1 for yes and 0 for no.

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. The codes create a classification system that differentiates metro counties by the population size of the metro area, and nonmetro 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 rurality in this analysis[4]. 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.

County-level economic and sociodemographic characteristics are taken from the 2000 US 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

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[4] 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.

inequality of incomes. Two key variables to come 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**.

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. Preliminary tests for multicolleniarity (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 multicolleniarity. Additional variables at the county-level were also found to be highly correlated. These include 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.

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 are 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.

Results from the factor analysis using the variables described above are found in Table 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 is very high. First is a health services factors that includes the total number of medical doctors (MD's), pediatricians, obstetricians/gynecologists, and 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 in this factor.

<Table 1 About Here>

The second factor captures economic measures of the county and consists of the percent of the county population aged 25 and over with a college education, the percent 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 **social environment 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[5]. **Putnam-type establishments** consist of the total number of bowling centers, public golf courses, membership sports and recreation clubs, civic and social

[5] 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.

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 variables 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 another dimension of the health service characteristics of the county.

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 weights as well as individual- and structural-level covariates. In this analysis, individual biological, social, and behavioral characteristics of infants and their families will constitute the level-I, or individual-level, variables. Level-II, or contextual, variables are detailed above and include residential, economic, 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. 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 US Census of Population and Housing Summary File 3, 2000 County Business Patters, 2000 Uniform Crime Reports, and 2004 Area Resource Files allows the opportunity to analyze average birth weight 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. Some counties had to be combined due to the sampling design of the ECLS-B and the small number of cases within individual counties.

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 on unobserved measures 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 software packages HLM 6, will provide more robust standard errors and unbiased estimates of the relationships with average birth weight and the odds 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.

Initial analyses using one-way analysis of variance (ANOVA) procedures test for differences in birth weights and the odds low birth weight status at level-II. This model reports the overall variability among true county means in the two outcomes of interest. 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 (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 the first model to be estimated. 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. Within-county variation is represented by σ^2 in the equation, while τ_{00} accounts for between-county variation. These two variance components determine the amount of variance attributable to each of the two levels in the model.

All level-I covariates are included in the next set of models in the analysis as controls, and level-II variable are added in a nested model format. Level-I one covariates are consistent across the models in order to control for individual-characteristics on the outcome variable, since results from preliminary results indicate that individual-level characteristics explain much of the variation in 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.

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

where

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

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

Level-II measures are added in a nested manner, with each of the characteristics represented by β_{0j} being added to the model with level-I controls. A population weight is assigned to the level-I one covariates in the model to make the results generalizable to all infants born in 2001.

A different set of assumptions are 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 techniques 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 variables 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

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

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 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.

Findings

Individual– and County–Level Characteristics

Table 2 presents the means or percentages and standard deviations for variables at level-II and standard errors at level-I for all variables contained in the multilevel models. The mean birth weight for infants in this sample is 3315.43 grams, or approximately 7.29 pounds. Individual births 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, a little more than seven 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 2. Some notable values at the individual-level include gestational age in weeks that has a mean of 38.75 weeks, indicating that on average infants are born full term. Gestational age ranges from 17 to 47 weeks. A very small number of all births, about 3 percent, result in twins. Mother's age at birth has a mean value of 27.32 years, but this value ranges from 15 to 50 years of age at the time of birth. A majority of women, 67 percent, are married when they give birth, and over half women have private health insurance. About eleven percent of women smoke while they are pregnant, while less than one percent of pregnant women consume alcohol. A large number of women, 40.26 percent, take advantage of the supplemental WIC program during pregnancy, which was shown to decrease the odds of having a low birth weight infant in preliminary analyses.

<Table 2 About Here>

Level-II, or county, covariates are also shown in Table 2. As would be expected the majority of the population of births in 2001 live in the most metro county designation, which are central metro counties with populations of one million or more. The most nonmetro counties have the smallest percentage of the total population of births.

Income inequality, captured here by the Gini coefficient, has a value of 0.45, indicating that income distributions are somewhat unequally distributed across counties. Values from the Gini coefficient range from 0.35 to 0.54 for the counties included in this sample. The national value for the Gini coefficient is 0.462, which is slightly higher than the value for the counties used in this analysis (U.S. Census Bureau 2004). Almost 13 percent of a county's population is composed of African Americans, ranging from 0.15 to 66.33 percent, while a little more than 14 percent of a county's population consists of Hispanics. The percent of county residents that are Hispanic ranges from 0.41 percent to 78.27 percent.

A larger number of Putnam-type establishments are found in each county (12.93) than Olsen-Type establishments (2.10). 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 3 displays means, standard deviations, and minimum and maximum values for selected county-level variables from Table 2.

<Table 3 About Here>

The average mean value is very different for many of the variables when comparing all counties in the US to counties used in this analysis. The ranges for variables in Table 3 are also quite different. The majority of individuals for the sample used in this analysis are largely from metro counties, as a result many of the other county-level variables are likely to represent characteristics of metro county populations. Therefore the variation in nonmetro county characteristics may be underrepresented in this sample. These differences in resources across counties are posited to lead to variation in 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 presents results from this analysis both with and without weighting. The significance level of the F-statistic for both the weighted (F=922.166) and unweighted (F=16.749) ANOVAs indicates that variation in birth weights do exist based on the rural-urban continuum code assigned to the infant's county of residence. In the weighted analysis, 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 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 About Here>

A similar pattern is observed for mean birth weights based on rural-urban continuum code designation when you look at the results from the analysis without weighting the data to all births in the population for 2001. Results from this analysis indicate that nonmetro infants weigh more at birth than the mean for the sample, which has a value of 2,927.44 grams. Even with differences in the total number of infants in each type of county designation, a statistically significant difference is found between birth weights in the analysis without weighting to the population of births for 2001. Based on results from these initial tests indicating differences in birth weight based on the rural-urban continuum codes for the infant's county of residence, multilevel methods are appropriate for modeling individual- and county-level variables to estimate birth weights.

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, not the sample from the ECLS-B.

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 than between-county variation. About five percent of total variation in average birth weights is attributed to between-county differences ($\tau_{00}/(\sigma^2 + \tau_{00})$ = 39,642.81/771,817.42), while within-county individual differences account for the remainder of the variation ($\sigma^2/(\sigma^2 + \tau_{00})$ = 732,174.62 /771,817.42). The large amount of variation between individuals is as 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 5 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 of rural-urban continuum code designations have a statistically significant relationship with average birth weight 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 mean birth weights that are 114.09 grams more than birth weights of infants in counties with the most metro county designations. 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 different significantly 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 preliminary analyses not shown here, which indicate that the shape of the relationship with age of the mother at 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 attend 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 birth weight.

<Table 5 About Here>

Economic 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 as significant negative relationship (-651.62) with birth weights, as would be expected. The value for this coefficient represents how much lower birth weights would be on average for individuals in counties that had total inequality in their income distribution. 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 mean birth weight in that county will be 110.40 grams less than counties without black residents (-5.52*20=110.40). Relationships between the rural-urban continuum code designations and birth weight remain the same, except for designation 8. No statistically significant relationship remains for this designation and birth weight with the addition of economic 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. There would be an additive effect for all infants in this metro county designation if the county has a high percentage of black residents.

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 are explained by this model.

Table 6 presents the remaining three models that incorporate other county-level characteristics. Model 4 in Table 6 adds in social capital characteristics at the county-level, both Putnam- and Olsen-type establishments. As the number of Olsen-type establishments increases in a county, 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 in the county. All other statistically significant relationships remain the same as in Model 3 in Table 4.

<Table 6 About Here>

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 for between the social environment 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 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 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.

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 higher or lower 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 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 7 presents results of the one-way analysis of variance (ANOVA) test. In models both with and without weighting to account for the oversampling of certain infants in the ECLS-B sample, a statistically significant difference exists in the odds of low birth weight status between the rural-urban continuum code designations.

<Table 7 About Here>

About seven percent of infants in the weighted data are likely to be born low birth weight. In both of these analyses, metro counties with a population between 250,000 and one million have the highest odds 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 odds of low birth weight status. While the variation between the designations is small, ranging between 0.03 points in the model with the data weighted to all births in the population for 2001, the variation remains statistically significant.

Low Birth Weight Status and County- and Individual-Characteristics

Variance components using Bernoulli estimation techniques for multilevel logistic techniques in HLM 6 are not estimated in the same manner as variance components with a continuous dichotomous 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. 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 8 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 a metro population of 20,000 or more are two-thirds less likely to be 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 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 as expected. 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.

<Table 8 About Here>

Economic characteristics of counties are added in Models 2 and 3 in Table 8. 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 infant in a county with no black residents. Relationships between the probability 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 in 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 = 0.15) 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 central metro cities with a population of one million or more. Odds ratios for county designations 5 and 6 only become 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 1.88 times more likely to be low birth weight than infants in central metro counties with a population of one million or more. The odd 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 to Model 4 in Table 9, the economic factor score is no longer statistically significant. Infants born in a county with a large number of Olsen-type establishments are 1.16 time 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 a likely to be low birth weight as infants born in the most metro county designation with a population of one million or more.

<Table 9 About Here>

Measures of the social environment and health services for counties are added in Model 5 and 6 in Table 9. While the social environment 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 social environment 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 low birth weight status in Model 6. A positive relationship exists between the coefficient for 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 three-fourths as likely to be low birth weight. With the inclusion of all county-level variables in Model 6, infants in nonmetro counties with a rural area or 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.

Discussion

This research examined the statistical relationship between individual- and structural-level characteristics and birth weight, both average birth weight 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, economic, 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 relationship with county-level characteristics with controls for individual-level covariates.

Results with the individual-level covariates in this analysis are as expected based on preliminary analyses, indicating that biological measures of the infant and mother are most important in determining variation in overall 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 social 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 and the odds low birth weight status in the population of births. First, one of the measures of social capital is important. Olsen-type establishments lower average birth weight and increase the odds that an infant will be low birth weight if the infant lives in a county with a large 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. 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, weight 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. Therefore the relative-income hypothesis is not supported in this research.

As for measure 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. Specifically infants in metro counties with a population between 250,000 and one million have lower overall birth weights and a greater likelihood of having a low birth weight infant. Of the nonmetro categories, infants in nonmetro counties with a rural area or 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. More consistency across studies examining differences in birth weight for rural and urban infants is needed based on the results in this chapter in order to frame more locally based health policies targeting women and infants in nonmetro counties.

Overall results from this research indicate that little variation exists in overall birth weight and low birth weight status at the county level. In order to tease out the differences in infant health outcomes by rurality status similar methods should examine infant mortality rates or common infant and childhood morbidity patters. However, results from this analysis support the need for contextual-level measures to be included with individual measures in order to assess the relationships between individuals and space for health outcomes.

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Table 1: Descriptive Statistics, Factor Loadings, Eigenvalues, and Explained Variance of Factor Solution for County-Level Measures

			Factor Scores		
Observed Variables	Mean	Standard Deviation	(1) Health Services	(2) Economic	(3) Social Environment
Percept 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

Table 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	Std Deviation or Error	Minimum	Maximum
Dependent Variables:				
Birth Weight in Kilograms	3,319.13	4.01	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		
Economic 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
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				
Social Environment 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	0.002		
Gestational age (weeks)	38.77	0.03	17.00	47.00
Twin (1=yes)	2.94	0.0004		
Maternal Complications	29.35	0.01		
Newborn Conditions	6.53	0.004		
Social Characteristics				
Mom Less than High School (reference)	21.19	0.01		
Mom High School	31.13	0.01		
Mom College	47.68	0.01		
Income	50,273.97	635.97	5,000.00	200,00.00
Health Insurance (1=yes)	53.02	0.01		
Mother's Age at Birth	27.32	0.03	15	50
Mother's Age at Birth Squared	784.71	1.41	225	2,500
White (reference)	58.80	0.001		
Black	13.77	0.002		
Hispanic	22.01	0.003		
Asian	3.42	0.001		
Other	2.30	0.002		
Married (1=yes)	67.50	0.01		
Behavioral Characteristics				
Smoke while Pregnant	10.82	0.004		
Drink while Pregnant	0.43	0.001		
Number Prenatal Visits	11.53	0.02	0	49
Weight Gain – Less than 25 Pounds (ref)	44.20	0.001		
Weight Gain – 25 to 34 Pounds	29.06	0.002		
Weight Gain – 35 to 40 Pounds	26.74	0.001		
Food Secure (1=yes)	89.91	0.01		
Pregnancy Wanted (reference)	84.48	0.003		
Pregnancy Not Wanted	8.87	0.003		
Pregnancy Not Sure	6.65	0.004		
WIC (1=yes)	40.26	0.01		

Table 3: Means and Standard Deviations for Selected Level-II Variables for All Counties in the US				
	Mean	Standard Deviation	Minimum	Maximum
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

Table 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	1,740,734
(1) Metro fringe, 1million or more	3,334.47	588.37	325,022
(2) Metro, 250,000 – 1 million	3,267.77	637.88	680,215
(3) Metro, less than 250,000	3,312.61	584.99	284,503
(4) Urban 20,000 plus, adjacent to metro	3,375.49	843.44	127,191
(5) Urban 20,000 plus, not adjacent to metro	3,305.83	508.28	101,193
(6) Urban 2,500-19,999, adjacent to metro	3,362.60	555.83	294,716
(7) Urban 2,500-19,999, not adjacent to metro	3,327.76	558.39	287,575
(8) Rural or less than 2,500, adjacent to metro	3,359.73	560.34	43,034
(9) Rural or less than 2,500, not adjacent to metro	3,313.00	502.10	55,150
Average Birth Weight for the Population of Births	*3,315.43*	*593.59*	*3,939,333*
F=922.166, p<0.001			
Without Weighting			
(0) Central metro, 1million or more	2,919.21	887.51	4,763
(1) Metro fringe, 1million or more	2,929.84	864.26	782
(2) Metro, 250,000 – 1 million	2,734.40	978.08	1,732
(3) Metro, less than 250,000	2,960.14	865.00	878
(4) Urban 20,000 plus, adjacent to metro	3,070.82	823.00	395
(5) Urban 20,000 plus, not adjacent to metro	3,152.72	675.25	311
(6) Urban 2,500-19,999, adjacent to metro	3,052.69	809.11	743
(7) Urban 2,500-19,999, not adjacent to metro	3,062.23	771.12	723
(8) Rural or less than 2,500, adjacent to metro	3,057.72	785.78	138
(9) Rural or less than 2,500, not adjacent to metro	2,951.55	792.46	143
Average Birth Weight for the Sample of Births	*2,927.44*	*882.72*	*10,608*
F=16.749, p<0.001			

Table 5: 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)
Economic 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			
Social Environment 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	-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

Table 6: 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)
Economic 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			
Social Environment 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	-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 for the rural-urban continuum codes is central counties of metro areas of 1 million population or more

Table 7: 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	0.08	0.27	1,755,793
(1) Metro fringe, 1million or more	0.07	0.25	328,737
(2) Metro, 250,000 – 1 million	0.09	0.29	692,934
(3) Metro, less than 250,000	0.07	0.26	288,005
(4) Urban 20,000 plus, adjacent to metro	0.07	0.25	131,538
(5) Urban 20,000 plus, not adjacent to metro	0.05	0.22	103,116
(6) Urban 2,500-19,999, adjacent to metro	0.06	0.24	299,687
(7) Urban 2,500-19,999, not adjacent to metro	0.06	0.24	292,287
(8) Rural or less than 2,500, adjacent to metro	0.07	0.26	43,085
(9) Rural or less than 2,500, not adjacent to metro	0.07	0.25	55,633
Average Odds Ratio for the Population of Births	*0.07*	*0.26*	*3,990,815*
F=615.596, p<0.001			
Without Weighting			
(0) Central metro, 1million or more	0.26	0.437	4,763
(1) Metro fringe, 1million or more	0.25	0.431	782
(2) Metro, 250,000 – 1 million	0.35	0.476	1,732
(3) Metro, less than 250,000	0.26	0.438	878
(4) Urban 20,000 plus, adjacent to metro	0.21	0.410	395
(5) Urban 20,000 plus, not adjacent to metro	0.14	0.352	311
(6) Urban 2,500-19,999, adjacent to metro	0.21	0.407	743
(7) Urban 2,500-19,999, not adjacent to metro	0.21	0.408	723
(8) Rural or less than 2,500, adjacent to metro	0.23	0.424	138
(9) Rural or less than 2,500, not adjacent to metro	0.25	0.436	143
Average Odds Ratio for Births in the Sample	*0.26*	*0.438*	*10,608*
F=13.060, p<0.001			

Table 8: 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)
Economic 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			
Social Environment 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	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 ≤.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

Table 9: 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)
Economic 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			
Social Environment 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	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