Public goods and private resources as determinants of county low birth weight incidence

by

David Stuart Curtis

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Approved by

Thomas Fuller-Rowell, Chair, Associate Professor of Human Development and Family Studies
Mona El-Sheikh, Leonard Peterson & Co., Professor of Human Development and Family Studies
Stephen Erath, Associate Professor of Human Development and Family Studies
Silvia L. Vilches, Assistant Professor of Human Development and Family Studies
Joseph Vonasek, Assistant Professor of Political Science

Abstract

Infants born at low birth weight are at elevated risk of infant mortality, developmental delays, and adulthood cardiovascular disease. That low birth weight (LBW; <2500 grams) incidence varies two-to-three-fold between racial/ethnic groups (e.g., black/African American relative to white) and across geographic areas (e.g., counties) is therefore a pressing public health concern. These differences in LBW incidence are at least partly due to the clustering of social and economic risks within historically marginalized racial groups and economically disadvantaged places, as well as dissimilar policy and community resource environments. In this dissertation, we seek to understand how differences in county incidence of LBW and county black-white disparities in LBW develop over time. Toward this end, we exploited within county changes in the provision of public services, and fluctuations in the private economic resources of residents, to understand their influence on LBW outcomes. Two studies presented herein use data from national birth records for fifteen years between 1992-2014, with data on birth weight and maternal characteristics aggregated to the county and pooled over three-year periods.

The first study examined whether changes in local government expenditures on two services (parks and recreation, and housing and community development) influenced county incidence of LBW and the black-white LBW gap. Local government expenditures were assessed every five years from 1992-2012 by the U.S. Census Bureau. Linear regression models were fit, adjusting for the lagged dependent variable, county and period fixed effects, local government expenditures in multiple categories, and county fluctuations in median income, percent of black

residents, and population change. Results indicated that increases in parks and recreation expenditures were associated with reduced county LBW incidence (a $50 increase per capita reduced LBW incidence by 1.25 births per 100) but not black-white LBW disparities.

In the second study, the primary aim was to test whether county fluctuations in median income were associated with LBW outcomes, and the extent to which this link was explained by maternal sociodemographic and health risk factors. Median income and black-white differences in income were assessed in years that corresponded to the five measurement periods for LBW outcomes. Using county by period fixed effects models, increases in median income were associated with reduced county LBW incidence and a shrinking black-white gap in LBW. The link between median income and county LBW incidence was attenuated by 72% when adjusting for maternal sociodemographic characteristics. Models in both studies were also fit using the more clinically significant outcome of very low birth weight (<1500 g.), and results were generally in accord. These studies document area level policy and economic determinants that could be targeted in local initiatives to reduce the incidence of LBW and promote greater equity in outcomes between black and white infants—namely, by increasing parks and recreation services and supporting economic development initiatives or policies that improve income levels.

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List of Abbreviations

LBW	Low birth weight
VLBW	Very low birth weight
PRS	Parks and recreation services
HCD	Housing and community development

General Introduction

The United States has high infant mortality (i.e., mortality in first year of life) relative to peer countries (Heisler, 2012). A substantial portion of the relatively high infant mortality in the U.S., in turn, can be attributed to elevated incidence of low birth weight (Heisler, 2012). Low birth weight (LBW; <2500 g.), stemming from fetal growth restriction (i.e., small for gestational age) or premature birth, is also one of the leading causes of infant mortality within the U.S. (Osterman, Kochanek, MacDorman, Strobino, & Guyer, 2015). Reducing infant mortality and LBW incidence are therefore key objectives of Healthy People 2020, which is a federal initiative that sets many national health priorities and research efforts (Healthy People 2020, 2010).

Geographic differences in adverse birth outcomes (i.e., infant mortality, low birth weight, premature birth) within the United States are also dramatic. State infant mortality rates range from 4.76 to 10.01 per 1000 live births (Mathews & MacDorman, 2013b). LBW incidence ranges nearly three-fold between multi-county areas (Thompson, Goodman, Chang, & Stukel, 2005), with implications for county differences in infant mortality. Such data suggest that efforts to improve birth outcomes will need to consider risk factors within local contexts, and that these efforts should be focused on areas burdened by a disproportionate share of high-risk births.

In addition, large disparities in adverse birth outcomes between black or African American (black) and white or European American (white) infants are present and have persisted throughout the history of the United States. In 2016, 13.7 per 100 black infants were born LBW relative to 7.0 per 100 white infants; the relative disparity was even larger for very low birth weight (<1500 g) with 3.0 and 1.1 cases per 100 births, respectively (Martin, Hamilton, Osterman, Driscoll, & Drake, 2018). Black-white disparities in infant mortality have been approximately two-fold since at least 1970 (Guyer & Strobino, 1996; Osterman et al., 2015), with more than half of the recent racial gap in infant mortality stemming from differences in LBW (MacDorman & Mathews, 2011). Black-white infant mortality ratios also show considerable variability between states, ranging from 1.6 to 3.3 (Mathews & MacDorman, 2013b), and variability between counties within states (Rossen, Khan, & Schoendorf, 2016).

That elevated incidence of LBW is a primary contributor to the relatively high infant mortality in the U.S., to variation in infant mortality between states or counties, and to mortality disparities between black and white infants is a key observation with implications for health initiatives (Heisler, 2012; Hirai et al., 2014; Mathews & MacDorman, 2013b). Specifically, a myopic focus on reducing congenital malformations and improving clinical care for high-risk deliveries—although worthy goals in themselves—may limit success in reducing the substantial international, geographic, and racial disparities in infant mortality. Rather, understanding the determinants of spatial variations in LBW incidence and black-white disparities will provide important intervention targets for policy makers and public health officials. Moreover, examining the influence of government policies and practices on LBW incidence and infant mortality may help inform effective initiatives to improve population-level birth outcomes and reduce disparities between black and white infants (Almond, Chay, & Greenstone, 2006; Grossman & Jacobowitz, 1981).

Additionally, LBW has long-term effects on morbidity, socioeconomic attainment, and well-being that are consequential for racial and geographic disparities in health, education, and economic gains in adulthood (Barker, 1995; Boardman, Powers, Padilla, & Hummer, 2002; Braveman & Barclay, 2009; Moster, Lie, & Markestad, 2008; Parkinson, Hyde, Gale, Santhakumaran, & Modi, 2013). Therefore, high incidence of LBW is of major concern to the long-term health and well-being of black Americans and residents of disadvantaged places.

Social and Policy Determinants of Adverse Birth Outcomes

The underlying mechanisms that influence LBW risk can be conceptualized at multiple levels, including maternal, household, neighborhood, and societal contributors. Although factors that are more proximate to the fetus (e.g., maternal health behaviors, maternal stress) are likely the direct contributors to fetal growth and gestational length (Giscombé & Lobel, 2005), environmental factors (e.g., residential segregation, neighborhood disadvantage, and wealth inequality) influence birth outcomes by shaping many proximate contributors (Blumenshine, Egerter, Barclay, Cubbin, & Braveman, 2010; Margerison-Zilko et al., 2015; Polednak, 1996; Siddiqi, Jones, Bruce, & Erwin, 2016). However, the majority of research into causes of adverse birth outcomes has focused on maternal risk factors during pregnancy (Kramer, Seguin, Lydon, & Goulet, 2000), with relatively little attention paid to ecological and policy influences.

A broad array of public policies exist that could have either direct or indirect influences on LBW risk and other adverse birth outcomes. Prior research has documented positive benefits of select programs, including food assistance (Almond, Hoynes, & Schanzenbach, 2011; Hoynes, Page, & Stevens, 2011), supplemental income (Hoynes, Miller, & Simon, 2015; Strully, Rehkopf, & Xuan, 2010), home visitation (Lee et al., 2009), and family planning services (Frost, Sonfield, Zolna, & Finer, 2014). Although these programs represent exciting opportunities for federal, state, and local governments to improve birth outcomes, the potential benefits of many other policies and government practices remain unknown.

One relevant example of understudied policies is the level of funding provided by municipality or county governments for public goods and services, such as parks, community centers, and public health clinics. Many of these services may influence health and social risk factors and therefore could reduce the incidence of adverse birth outcomes. This topic is particularly important given that county governments have substantially increased their role as providers of public goods and services in recent decades (Benton et al., 2007). However, very few studies have examined how spending in specific domains is linked to changes in population health (Bekemeier, Yang, Dunbar, Pantazis, & Grembowski, 2014; McCullough & Leider, 2016). In terms of adverse birth outcomes, the only relevant studies to our knowledge have shown that spending on public health is associated with reduced infant mortality (Bekemeier et al., 2014; Grembowski, Bekemeier, Conrad, & Kreuter, 2010), while spending on hospitals is associated with *increased* infant mortality (Matteson, Burr, & Marshall, 1998). Recent findings have documented the health benefits of spending on specific public services (e.g., education, libraries), as well as county government spending profiles (e.g., high expenditures on housing and community development and parks and recreation); however, these studies have only used a non-specific indicator of county health rankings (McCullough, 2017; McCullough & Leider, 2016). Furthermore, little research has examined how local government spending could differentially impact social groups within geopolitical designations (Bekemeier, Grembowski, Yang, & Herting, 2011; Grembowski et al., 2010).

Advantages of Understanding County Determinants

Modeling counties as a substantive unit of analysis affords several benefits to population health research and health policy. First, in comparison to small areas (e.g., census tracts), data on birth outcomes are readily available to researchers and local public health officials. Such data availability facilitates public health surveillance and the modeling of area risk factors. Second, relative to interstate or international differences, between county comparisons afford attention to the heterogeneity existing within larger areas. In particular, when focusing on differences in birth outcomes between states, researchers obscure substantial variation in socioeconomic and health factors that exist between counties within states (Egen, Beatty, Blackley, Brown, & Wykoff, 2017). Several states, for instance, have counties that rank in the bottom *and* top 2% of median household income, an economic indicator that is highly correlated with health outcomes across the lifespan (e.g., infant mortality, life expectancy) (Egen et al., 2017). Lastly, between-county comparisons allow for examination of local policies or the provision of resources as they relate to birth outcomes (Bekemeier et al., 2014; Grossman & Jacobowitz, 1981).

Despite the aforementioned benefits, modeling county incidence rates are insufficient in important ways (Clark & Williams, 2016; Greenland, 2001). One notable limitation is that population-wide health outcomes hide important within-county health differences—differences that are often characterized by race/ethnicity, social class, place, or other indicators of social position. For example, a large majority population with high health status could mask substantial health risks experienced by a small subset of the population. Given that high-risk subsets of the population are often the target of public health efforts, such masking does not represent a trivial oversight in the data modeling strategy. This distinction between population health and health disparities demonstrates the need for each of these health indicators to be explicitly modeled in research on area effects (Kindig, Asada, & Booske, 2008).

Present Research Studies

The present dissertation consists of two studies that examine how changes in public services and fluctuations in private resources within counties influence LBW incidence. Another primary aim is to consider determinants of county-specific racial disparities in LBW incidence between black and white infants. Because of the potential for many collinear influences to be operating simultaneously in cross-sectional data and the disparate governments and populations of counties, we focus the present research on within county fluctuations in predictor and outcome variables. More specifically, data on birth weight and maternal sociodemographic and health characteristics were aggregated to the county level from birth records across a total of 15 years (three-year pooled estimates are coded for five periods). Data from corresponding time periods that represent local government expenditure patterns, county median income, and population estimates were gathered from multiple U.S. Census Bureau sources. The studies seek to answer the following two broad questions:

1. Do increases in local government spending on (1) parks and recreation services or (2) housing and community development programs influence county incidence of LBW and the black-white gap?
2. Are fluctuations in (1) median household income and (2) black-white differences in income associated with county incidence of LBW and the black-white gap, and to what extent are these associations explained by maternal sociodemographic and health risks?

Study 1 – Changes in Parks and Recreation Expenditures and Incidence of Low Birth Weight: Evidence from Five Periods of National Birth Records Data

Abstract

Local governments play an integral role in providing health-relevant services (e.g., parks and recreation [PRS], housing and community development [HCD]) to their residents, yet the population health implications are frequently overlooked. Such services may be particularly beneficial to groups who otherwise would lack access. The present study examined how changes in local government expenditures for PRS and HCD, assessed on five occasions between 1992 and 2012, influence county incidence of low birth weight and black-white disparities. In a sample of 956 counties with a total of 3619 observations, bias-corrected county by period fixed effects models were fit using bootstrap samples to derive estimates of the impact of PRS and HCD expenditures on low birth weight incidence. Time-varying covariates included the lagged dependent variable, government expenditures (total, health, and hospitals), and income and demographic covariates. Results indicate that an increase in PRS expenditures of $50 per capita was associated with 1.25 fewer cases of LBW per 1000 singleton births. Some evidence was also found for increases in HCD expenditures being associated with declining LBW incidence. Changes in PRS and HCD were not linked to the county black-white gap in low birth weight incidence, but health expenditures in the prior period led to a declining racial disparity. Increasing PRS represents a novel policy through which local governments can improve birth outcomes among residents.

Local governments provide a range of services that could impact maternal and infant health. Obvious examples include health and hospital services, (Bekemeier et al., 2014; Grembowski et al., 2010), yet many other social programs or public goods (e.g., housing, parks) may have a positive influence. Notably, among states in the U.S. and OECD countries, higher levels of government spending on social services relative to healthcare are associated with better population health outcomes (Bradley et al., 2016; Bradley, Elkins, Herrin, & Elbel, 2011). For U.S. counties, increasing expenditures on housing and community development, K-12 education, and other social services have been linked to improved county health rankings (McCullough & Leider, 2016). The potential health benefits of many local government programs, however, are not well understood. Such a gap in extant literature is notable given that local governments have substantially expanded their role as service providers in recent decades (Benton et al., 2007; Lobao & Kraybill, 2005), and therefore have potential to influence many social and behavioral determinants of health among residents. Because the aim of social programs and public goods is often to meet the needs of under-resourced groups, increasing spending on public services could also promote greater health equity within areas (Whitehead, 2007). The current study estimates the association between changes in local government spending for (1) housing and community development (HCD) or (2) parks and recreation services (PRS) and county low birth weight distributions (i.e., overall incidence and black-white disparities).

County-Level Variation in Birth Outcomes

Substantial variations in birth outcomes exist between counties; for example, low birth weight (LBW) incidence ranges nearly least three-fold between multi-county areas (Thompson et al., 2005). LBW incidence and infant mortality are also higher among black infants relative to whites in every county in the U.S. (Rossen et al., 2016; Thompson et al., 2005). The magnitude of the black-white disparity in adverse birth outcomes is wide-ranging between counties, however, with some faring more favorably in terms of equity between racial groups while others have a large racial gulf (Kramer & Hogue, 2008; Rossen et al., 2016). Due to the risk of infant mortality that accompanies LBW status and its potential lifelong influence on cognitive functioning and cardiovascular health, particularly at more extreme low birth weights (Barker, 1995; Boardman et al., 2002), geographic and racial differences in LBW incidence likely have implications for group disparities in health and socioeconomic attainment (Braveman & Barclay, 2009). Understanding how policies and government practices influence incidence of adverse birth outcomes and area-level disparities is therefore critical in efforts to promote population health and address enduring differences between black and white Americans. Despite a few notable examples (Grossman & Jacobowitz, 1981; Hoynes et al., 2011), counties have rarely been considered as a unit of analysis through which to examine the influence of social policies on adverse birth outcomes.

One potential contributor to county variations in birth outcomes and associated racial disparities is the availability of social services and public goods (e.g., Khanani, Elam, Hearn, Jones, & Maseru, 2010). Social services are often directed at individuals or communities with limited economic supports—who also tend to have elevated health risks. Even though public goods by definition are non-exclusionary and can be jointly consumed (Ostrom & Ostrom, 1977), individuals who lack financial resources to obtain access to private goods may disproportionately utilize their public equivalents (Becker et al., 2010). Local government efforts to increases the availability of health-promoting public goods may therefore especially benefit the health of under resourced groups. Ensuring ready access to an array of public services and goods—e.g., by providing opportunities for physical activity, education, and affordable housing—could partially equilibrate the substantial black-white gap in resource availability, and therefore lead to smaller racial health disparities (Alexander, Huber, Piper, & Tanner, 2013). An important research endeavor is thus to elucidate how spending on public goods and social services influences area-level health outcomes and health disparities.

Local Government Expenditures as Levers for Health

Recent increases in service provision by local governments, especially among counties, represent a substantial expansion of role, with spending levels rising across the majority of public services (Benton et al., 2007; Lobao & Kraybill, 2005). Thus, local governments may have become more important to the health of their residents—for example, by investing in community infrastructure, providing public health services, and increasing the availability of public goods (i.e., libraries, parks). Trends in spending levels and patterns, however, have not been uniform across county and local governments; rather, changes often reflect distinct shifts in governance and the agendas of local politicians and constituents (Jordan, 2003). Sudden increases in spending could also reflect the receipt of grant funding from federal or state governments, particularly in the case of housing and community development (Galster, Walker, Hayes, Boxall, & Johnson, 2004). Understanding whether the provision of local government services contributes to area-level economic conditions, human capital, and health and well-being could guide future decision making within local governments. In addition to considering targeted benefits of services, the indirect effects on population health also need examined. Among others, two government expenditure categories are likely to have broad influences on health and birth outcomes—namely, HCD and PRS.

Housing and community development. Local governments frequently have programs designed to renew urban centers, increase affordable housing stock, and offer housing vouchers (Howell, 2016), even when the funding comes through federal grants (Galster et al., 2004). Such initiatives could benefit human health given that affordable housing in safe neighborhoods is a key health resource for families (Evans, Wells, & Moch, 2003; J. Krieger & Higgins, 2002). Specifically, neighborhood economic disadvantage, housing instability, and homelessness are all risk factors for LBW (Carrion et al., 2015; Metcalfe, Lail, Ghali, & Sauve, 2011; Richards, Merrill, & Baksh, 2011). Neighborhood walkability has also been linked with maternal outcomes relevant to fetal growth, such as reduced likelihood of maternal smoking during pregnancy and insufficient gestational weight gain (Messer, Vinikoor-Imler, & Laraia, 2012). Notably, secular trends in the 1990s into early 2000s indicate consistent overall increases in local government spending on HCD, rising to just under 3% of total expenditures (Kaczynski & Crompton, 2006). These increases in HCD expenditures have also been linked with improvements in county health rankings (using a non-specific aggregate composite; McCullough & Leider, 2016). However, no prior studies have focused on whether spending levels by local governments on HCD influence birth outcomes, or within-area group disparities in health.

HCD programs could differentially influence LBW incidence for black and white infants. Black adults are more likely to reside in economically disadvantaged urban centers relative to whites (Massey & Denton, 1993; Williams & Collins, 2001) and to be recipients of public housing (Goetz, 2011). Racial residential patterns are also starkly segregated in many US counties, leading to under resourced communities, with the potential to increase LBW risk for black mothers (Mehra, Boyd, & Ickovics, 2017). Thus, HCD programs represent one policy lever that could produce greater equity in outcomes between black and white infants.

Parks and recreation. Another potential avenue through which local governments can promote the health of their residents is by increasing the availability of recreational programs, access to green spaces, and area walkability (Hunter et al., 2015; Sugiyama, Leslie, Giles-Corti, & Owen, 2008; Wells & Evans, 2003; Wells, Evans, & Yang, 2010). Residential greenness and proximity to parks have been associated with lower LBW incidence (Banay, Bezold, James, Hart, & Laden, 2017; Grazuleviciene et al., 2015)—a link that is partially mediated by increased maternal physical activity and reduced maternal depression (in the case of residential greenness; McEachan et al., 2015). Research into potential maternal and infant health benefits of spending on PRS, however, has been sparse. PRS spending has been found to be higher in counties with positive health factors (using an aggregate of health behaviors, clinical care, social and economic factors, and physical environment), but increases in county government spending on PRS were not predictive of changes in county health rankings (McCullough & Leider, 2016). In contrast, increases in state spending on PRS are linked with increases in physical activity and outdoor recreation (Cawley, Meyerhoefer, & Newhouse, 2007; Humphreys & Ruseski, 2007). It is therefore encouraging that spending on PRS has risen consistently in recent decades, even if the relative share of spending is just over 2.5% of total expenditures (Kaczynski & Crompton, 2006).

Expanding PRS could also influence black-white disparities in birth outcomes. Although nationally black Americans live in greater proximity to parks relative to whites (Wen, Zhang, Harris, Holt, & Croft, 2013), black-white disparities in access to safe, high-quality parks often exist (Dahmann, Wolch, Joassart-Marcelli, Reynolds, & Jerrett, 2010; Dai, 2011; Taylor, Floyd, Whitt-Glover, & Brooks, 2007). Additional funding for PRS could reduce these disparities in access to attractive recreational facilities. Moreover, PRS access may be especially health-promoting for black Americans. In one nationally representative study, access to parks or recreational facilities was associated with reduced childhood obesity risk, with larger associations for black relative to white children (Alexander et al., 2013). Understanding whether provision of PRS can promote greater equity in birth outcomes could guide future policy development.

Study Hypotheses

The aim of this study was to test whether changes in local government expenditures on HCD or PRS have influenced county LBW incidence and the black-white LBW gap. No prior studies, to our knowledge, have estimated the impact of increasing HCD or PRS spending on birth outcomes. Variation in service provision between government units as a determinant of area-level group disparities in health is particularly an understudied topic in extant literature. Utilizing data from nearly a third of US counties, county by period fixed effects models were estimated to test the following study hypotheses:

H_1: Increases in local government expenditures on (1) HCD and (2) PRS are associated with reduced county incidence of LBW.

H_2: Increases in local government expenditures on (1) HCD and (2) PRS are associated with shrinking disparities in county LBW incidence between black and white infants.

Methods

Data

Data for the present study were derived from multiple sources. National birth records from 1992 to 2014, initially collected through the National Vital Statistics System, were obtained from the National Center for Health Statistics. Nearly all births in the United States are included in national birth records in recent decades (Schoendorf & Branum, 2006). Restricted access datasets with county identifiers (i.e., Federal Information Processing Standards or FIPS codes) allowed birth records to be aggregated to the county and merged with data on local government expenditures, and county economic and population characteristics.

Inclusion criteria were initially applied to individual birth records and subsequently to county aggregate data. In particular, only singleton births to non-Hispanic white and non-Hispanic black women were included due to our focus on black-white disparities in birth outcomes, leaving a sample of 41.02 of 60.68 million total births. Three-year pooled aggregates of county-level incidence of LBW were then coded (discussed below) and represent the following years: 1992-1994; 1997-1999; 2002-2004; 2007-2009; and 2012-2014. Additional inclusion criteria were applied, such that counties had 1) at least ten cases of LBW for each racial group (i.e., black and white) to improve the reliability of estimates; 2) two consecutive periods that include concurrent and lagged data; and 3) data for government expenditures and other county variables. Selection criteria resulted in a population of 956 counties, with an average of 3.8 of 4 observations and a total of 3619 observations (the first of five periods was only included as a lag). Excluding the first period, these county-by-period observations represent 24.08 million births or approximately one-half of total births (and 73% of singleton births to black or white mothers). Counties included in the analytic sample are shown in the Appendices as Figure S1.

Local government expenditures were collected by the U.S. Census Bureau as part of the Census of Governments. The Census of Governments is conducted every five years (those ending in 2 and 7), and collects financial information from nearly all counties, municipalities, townships, and special districts—equaling approximately 87,000 local government units. Local government financial data for years 1967-2012 have been merged together by Pierson, Hand, and Thompson (2015), and are available publicly as the Government Finance Database. This database and accompanying documentation are available at http://www.willamette.edu/mba/research_impact/public_datasets/. Fiscal years 1992, 1997, 2002, 2007, and 2012, corresponding to the birth cohort periods, were selected for the present analyses and span a time-period with considerable increases in service expansion (see Figure 1 for timeline of measurement occasions for government expenditure and natality data, and hypothesized associations). Note that expenditures generally occurred in the prior year as roughly approximated on Figure 1. However, fiscal years are specific to each local government; specifically, reports were for the fiscal year concluding between July 1 of the previous year through June 30 of the survey year (e.g., 07/01/1996 to 06/30/1997 for fiscal year 1997).

County median household income and population estimates for periods corresponding to birth outcomes data were available through U.S. Census Bureau programs—namely, the Small Area Income and Poverty Estimates program and the Housing Unit and Population Estimates program, respectively.

Measures

Low birth weight. Birth weight, recorded on individual birth records, was coded as LBW when less than 2500 grams (Northam & Knapp, 2006). Records were aggregated to the county as incidence of LBW per 100 live births among black and white infants, and absolute difference in LBW incidence between black and white infants. LBW outcomes were pooled over three-year periods corresponding to expenditure assessments. Years were omitted between periods to improve the temporal ordering of local government expenditures and LBW incidence.

Maternal race. Race and Hispanic origin of mother were collected via birth certificates (Ingram et al., 2003), and classifications of non-Hispanic white and non-Hispanic black were used as an inclusion criterion and to determine the race-specific LBW incidence.

Local government expenditures. Two categories of expenditures were considered substantively in the present study: (1) housing and community development (HCD; e.g., rent subsidies, promotion of home ownership, urban renewal); and (2) parks and recreation (PRS; e.g., park maintenance, provision of recreational and cultural-scientific facilities) (Pierson et al., 2015). Three expenditure categories were modeled as covariates to reduce potential confounding influences: (1) total operational costs; (2) health (e.g., public health administration, community health care, health education, mental health services, regulation of air/water, excluding hospitals); and (3) hospitals (e.g., government's own hospitals and expenditures for the provision of care in public or private hospitals, excluding payments for medical services under welfare or medical assistance programs). Detailed description of the expenditure categories can be found in the Government Finance and Employment Classification Manual, found at https://www2.census.gov/govs/pubs/classification/2006_classification_manual.pdf.

Expenditures for each category were defined as operational costs—including direct employee compensations, and costs for supplies, materials, and contractual services, and excluding capital outlay and intergovernmental transfers. Intergovernmental transfers to other local governments were excluded to remove the possibility of double counting. In other words, intergovernmental transfers were excluded but the ensuing operational costs by another local government entity were counted. Similarly, local government operational costs financed through receipt of federal and state grants or transfers were included. Operational costs are stable year-to-year, relative to capital outlay, such that variation likely reflects distinct shifts in priorities and changes in service provision (Jordan, 2003; Kaczynski & Crompton, 2006). Expenditure levels are not a measure of the quality of service provision, however, and could be influenced by overhead or employee costs that do not influence the availability of services. Values were adjusted for population size and inflation by converting expenditures to per capita 2012 dollars.

Expenditures for county governments and sub-county general purpose and special purpose governments (i.e., municipalities, townships, special districts) were aggregated to the county level. Modeling all local government expenditures has the advantage of more accurately measuring local service provision, particularly in the Northeastern region and other areas where county governments serve a relatively limited role (Schneider & Park, 1989).

County sociodemographic covariates. To adjust for potential confounding variables, county median household income, percent of residents who are black (i.e., black density), and population change were included as time-varying covariates. Estimates for median household income were derived using data from administrative tax records, government transfers, decennial Census statistics, and the Current Population Survey or American Community Survey (Bell et al., 2007). Where possible, inflation adjusted three-year averages were computed (1993, 1997-1999, 2002-2004, 2007-2009, and 2012-2014). Population estimates were selected to correspond to the midpoint of birth outcome periods: 1993, 1998, 2003, 2008, and 2013. Black density was coded as the percentage of total residents categorized as non-Hispanic black, and population change since the prior period was computed and divided by prior period population (i.e., % change between periods).

Analyses

First, descriptive statistics and histograms were examined for raw and county mean-centered variables. Outlier data points were winsorized at 4 SD units to reduce violations of linear model assumptions. Means and standard deviations were examined by period to inspect changes in local government expenditures. To ensure that simultaneous consideration of multiple government expenditure categories would not introduce multicollinearity, bivariate correlations were examined using county-mean centered variables. To test study hypotheses, county by period fixed effects models were employed in which variance attributed to time-invariant between-county differences as well as period effects was removed from statistical models. The advantage of this approach is that omitted variable bias is reduced as all stable between county differences are controlled (Allison, 2009). This was accomplished using a fixed effect estimator that computes within-county mean deviations for all variables and error terms. Dummy variables representing periods were also included to adjust for sample wide averages at each of the time-periods, accounting for national secular trends that could confound associations between expenditure levels and birth outcomes. Random effect models using county-mean centered variables were also considered, but the Hausman test indicated that fixed effect models were preferred (Hausman, 1978).

All models included the lagged dependent variable. Due to a well-known downward bias of coefficients in dynamic panel models with a fixed time series and small number of time periods—arising from a correlation between the lagged dependent variable and the unit-period specific error term (Nickell, 1981)—bootstrap-based bias-corrected fixed effects models were fit using the XTBCFE command in STATA v. 14.2 (De Vos, Everaert, & Ruyssen, 2015; Everaert & Pozzi, 2007). Two hundred bootstrap samples were used for bias correction, and 100 bootstrap samples to estimate standard errors. A randomized temporal heteroscedasticity resampling scheme was selected, which resamples over time and within cross-sections and is appropriate for short time series and cross-sectional dependence (De Vos et al., 2015). The XTBCFE command can also handle higher order dynamic models with multiple time lags, a feature used for alternative lag specifications described below.

The model progression occurred similarly for LBW incidence and the black-white gap in LBW incidence. Initially, concurrent local government expenditures in the five aforementioned categories (i.e,. housing, parks, total, health, and hospitals) were included as predictors of low birth weight incidence, alongside the lagged dependent variable and period dummies (Model 1). Lagged local government expenditures for each of the five categories were added in Model 2. Time-varying county covariates were added in Model 3—specifically, median household income, black density, and population change, shown by the following model:

$$Y_{ti} = a_i + \gamma Y_{(t-1)i} + b_1 HCD_{ti} + b_2 HCD_{(t-1)i} + b_3 PRS_{ti} + b_4 PRS_{(t-1)i} + \beta_5 x_{ti} + \beta_6 period + e_{ti}$$

where Y_{ti} refers to LBW incidence at period t in county i; a_i is the time-invariant county effect; $Y_{(t-1)i}$ is LBW incidence lagged by one period; γ is the autoregressive coefficient for lagged LBW incidence; b_1 through b_4 refer to the coefficients representing the association between HCD and PRS expenditure levels and LBW incidence, both at period t and t-1, $\beta_5 x_{ti}$ is a vector of time-varying covariates that include concurrent and lagged total operational costs, health expenditures, and hospital expenditures, and median household income, black density, and population change; $\beta_6 period$ is a vector representing period dummy variables; and e_{ti} is the error for period t in county i.

The second series of models (Models 4, 5, and 6) substituted the black-white absolute gap in LBW as the outcome (Y_{ti}) and adjusted for the lagged black-white gap in LBW ($Y_{(t-1)i}$).

Several alternative model specifications and supplemental models were also considered. First, HCD and PRS expenditures were examined in separate models, adjusting for county and period effects, total expenditures, and county sociodemographic covariates. Second, alternative lag specifications were considered with reference to both LBW outcomes. Specifically, dependent variables and local government expenditures were lagged for two periods (i.e., *t*, *t*-1, *t*-2) to examine the long-run impact of PRS and HCD. Third, models were fit using more restrictive inclusion criteria, such that all counties had at least 20 cases of LBW for each racial group per period (n = 700 counties and 2611 county-by-period observations).

Supplemental models were estimated in which very low birth weight incidence (VLBW; i.e., number of births of less than 1500 g. per 1000 live births) and the black-white gap in VLBW incidence were considered as outcome variables. Examination of VLBW incidence leads to a substantial reduction in the analytic sample of counties (n = 387) because of the inclusion criteria that counties have at least ten cases of VLBW for both black and white infants. The advantage of examining VLBW, however, is that the immediate clinical significance and long-term sequelae of VLBW are much greater relative to cases of moderate low birth weight (1500 – 2499 g.) (Boardman et al., 2002; Wise, 1993). Moreover, the relative racial disparity in VLBW is approximately three-fold and is the largest contributor to racial differences in infant mortality (Mathews & MacDorman, 2013a). We present results for LBW and VLBW incidence to capitalize on the advantages of each outcome.

Results

County descriptive statistics for each period are shown in Table 1. As expected based on inclusion criteria, counties in the analytic sample (N = 956) were more populous, had higher black density, and higher median household income relative to excluded counties (using county mean values across measurement occasions; all p values < .001). In addition, sample counties had higher LBW incidence (p <.001). Differences in the magnitude of the racial gap in LBW were not considered due to unreliable estimates among excluded counties. Sample counties also had slightly lower levels of mean total operational expenditures per capita (p < .001), yet higher expenditures on parks (p =.010) and housing (p < .001). Across the five measurement occasions, mean local government total operational costs were $3,235 per capita in 2012 dollars, and only relatively minor shares of expenditures were for HCD (1.9%) and PRS (1.5%). Average HCD expenditures increased from $43 to $74 per capita between 1992 and 2012, and PRS expenditures increased from $38 to $53. Within county fluctuations in total operational costs were weakly-to-moderately correlated with fluctuations in HCD, PRS, health, and hospital expenditures (*r* coefficients ranged from .23 to .55), whereas fluctuations between the other expenditure types were at most weakly intercorrelated (*r*s < .17).

Local Government Expenditures and County-level Low Birth Weight Incidence

Results are shown in Table 2 for fixed effect models in which county incidence of LBW per 100 live births was modeled as the outcome. Adjusting for lagged LBW incidence$_{(t-1)}$, county and period effects, and concurrent total operational, health, and hospital expenditures, Model 1 results indicate that higher levels of concurrent PRS expenditures were associated with a decrease in LBW incidence relative to the prior period. For example, higher spending of $50 per capita in PRS expenditures by local governments is estimated to reduce county LBW incidence by 1.25 births per 1000, equivalent to .18 SD units of within county variance in LBW. HCD expenditures were not significantly associated with changes in LBW incidence (p = .15).

Lagged local government expenditures were added in Model 2. Neither PRS nor HCD expenditures from the prior period were associated with change in LBW incidence. Conditioning on prior spending did not substantively alter estimates for concurrent PRS and HCD expenditures (inclusion of county fixed effects meant that county mean PRS and HCD were already adjusted). When further adjusting for county time-varying median household income, black density, and population change (see Model 3), the association between changes in PRS expenditures and LBW incidence was of comparable magnitude to the earlier estimate and significant. Changes in HCD expenditures (i.e., concurrent levels adjusting for prior spending) were now marginally associated with reduced LBW incidence at $p = .085$. Specifically, an increase of $50 per capita on HCD is estimated to lead to .47 fewer cases of LBW per 1000 live births. In alternative model specifications where PRS and HCD were examined separately—adjusting for time and county effects, total operational costs (t, t-1) and county income and demographic covariates—results were similar but indicated a larger effect of HCD expenditures. Specifically, an increase of $50 in HCD expenditures led to .60 fewer LBW cases per 1000 births (95% CI: -1.15, -0.06; $p = .030$). Increasing PRS expenditures by $50 reduced LBW incidence by 1.15 cases per 1000 births (95% CI: -2.02, -0.27; $p = .010$).

An additional lag for local government expenditures (i.e., $t - 2$) was added to Model 3 to determine the long-run impacts of PRS and HCD. The additional lag resulted in a loss of one period and reduced the sample of counties to 899 with 2606 total observations. Results indicated that neither PRS nor HCD expenditures from two periods earlier were associated with LBW incidence ($p = .29$ and $p = .70$, respectively). In this model, however, concurrent PRS expenditures were associated with reduced LBW ($p = .007$) and the long-run impact of PRS expenditures (computed as the sum of t, $t - 1$, $t - 2$) was relatively large and significant; the estimated ten-to-twelve-year impact of $50 increase in PRS expenditures is 4.41 fewer LBW cases per 1000 births (Wald $\chi^2 = 3.01$ [3, 1685], $p = .029$). Considering multiple lags likely introduces bias into estimates due to overspecification, particularly with a short time series, and therefore these results should be interpreted cautiously but merit further research. The long-run impact of HCD expenditures was not significant (Wald $\chi^2 = 0.42$ [3, 1685], $p = .74$).

When more restrictive inclusion criteria were implemented requiring 20 cases of LBW for each racial group (n=700 counties, 2611 county-by-period observations), findings were similar in direction but estimates were smaller in magnitude and nonsignificant. In particular, adjusting for covariates listed in Model 1, a $50 increase in PRS had an estimated impact of .79 fewer LBW cases per 1000 live births (95% CI: -1.98, 0.41, $p = .20$). The equivalent estimate for HCD was also nonsignificnat ($p = .52$).

Local Government Expenditures and the Racial Gap in Low Birth Weight Incidence

Results for fixed effect models in which the county gap in LBW incidence between black and white infants was modeled as the outcome are shown in Table 3. Estimates from Model 4 indicate that concurrent HCD and PRS expenditures were not associated with the county racial gap in LBW, after adjusting for the lagged dependent variable, time-invariant county effects, period effects, total operational costs, and health and hospital expenditures. The estimated effect of PRS expenditures is of considerable magnitude but the standard error is wide. Lagged expenditures$_{(t-1)}$ were added in Model 5 and neither HCD or PRS were found to be significant predictors. Of the other expenditures, however, lagged health expenditures were associated with a reduced racial gap in LBW incidence ($p < .001$). Higher expenditures of $50 per capita in the prior period is estimated to reduce the black-white gap in incidence of low birth weight by 1.46 cases per 1000 live births approximately five-to-seven-years later. Estimated associations were comparable in Model 6 when adjusting for time-varying median household income, black density, and population change.

Alternative model specifications were examined. When HCD and PRS were considered in separate models, adjusting for total operational costs and income and demographic covariates, neither expenditure was significant. HCD and PRS were also not significant predictors in models that required 20 LBW cases per racial group. Additional lag specifications were added to consider long-run influences of local government expenditures from the two previous periods. Results from this model indicated that neither housing$_{(t-2)}$ nor parks$_{(t-2)}$ expenditures were associated with the racial gap in LBW incidence. None of the other two period lags of local government expenditures were associated with the racial gap in LBW incidence.

Local Government Expenditures and Very Low Birth Weight Outcomes

Very low birth weight (VLBW) incidence was also modeled as the outcome. Full model results are shown in Table S1 in the appendices. The analytic sample was reduced to 387 counties with the total number of observations being 1427. In model 3, adjusting for other expenditures$_{(t,\ t\ -\ 1)}$ and county demographic and economic covariates, concurrent PRS expenditures were not significantly associated with VLBW incidence but the estimated association was in the expected direction (Est. = -.31, 95% CI: -.74, .13). A $50 increase per capita in PRS expenditures was estimated to reduce the incidence per 1000 live births by .15 cases, equivalent to .89 SD units of within county variance in VLBW.

Model results for county black-white differences in VLBW incidence are shown in Table S2. Findings were generally similar to models considering the racial gap in LBW. Specifically, neither lagged nor concurrent HCD or PRS expenditures were associated with the racial gap in VLBW incidence. However, lagged health expenditures$_{(t\ -\ 1)}$ were associated with a smaller racial gap in VLBW incidence (Est. = -.65, 95% CI: -1.25, -.05). Higher per capita spending of $50 on health services had a lagged impact on the black-white VLBW gap, such that the disparity was reduced by .33 cases per 1000 live births.

Discussion

The current study is the first to provide evidence of the impact of local government expenditures on housing and community development as well as parks and recreation services on area-level distributions of LBW incidence. Given the substantial public resources allocated to these programs—albeit arguably insufficient resources (Godbey, Mowen, & Ashburn, 2010)—it is important that the wide-ranging benefits or lack thereof are well understood. We find that an increase in expenditures on PRS services over a five-year period is associated with a decrease in county LBW incidence over a corresponding period. Specifically, an additional investment of $50 per capita on PRS is estimated to reduce LBW incidence by 1.25 cases per 1000 live births. Although such a reduction may be judged to be a small effect, it would amount to approximately 1/3 of the Healthy People 2020 goal for reducing national LBW incidence, which is 4 fewer cases per 1000 live births, and is therefore of considerable value at the population level. Our study findings are broadly consistent with research on the salubrious effects of green spaces on maternal health and pregnancy outcomes (Banay et al., 2017). The majority of this research has investigated residential greenness (i.e., density of vegetation), however, with relatively little attention given to examining the association between access to park services and birth outcomes (Grazuleviciene et al., 2015). The present findings demonstrate the value of such research.

One potential explanation for the reduced LBW incidence is that increasing PRS spending improved women's health in preconception and prenatal periods (e.g., by improving opportunities for physical activity and social interactions). That spending on PRS promotes activity has been supported by findings that show increases in state spending on PRS leads to more frequent exercise and time spent engaging in outdoor recreation (Cawley et al., 2007; Humphreys & Ruseski, 2007). In addition, a randomized trial that included the provision of a small sum of $4,000 to selected parks as well as information about marketing to park directors and advisory boards increased exercise among community members while being cost-effective (Cohen et al., 2013). In turn, regular physical activity and time spent among greenery during pregnancy could improve pregnancy outcomes (Banay et al., 2017; Leiferman & Evenson, 2003). Another potential mechanism for the effects of increases in parks and recreation services on LBW risk is through influencing fertility timing and patterns. In particular, prior research has shown that involvement in recreational activities can encourage positive youth development (Eccles, Barber, Stone, & Hunt, 2003), manifesting in fewer risky behaviors, social skill formation, and higher educational attainment (Cohen, Taylor, Zonta, Vestal, & Schuster, 2007; Pfeifer & Cornelissen, 2010). Such accrued developmental benefits are likely to influence sexual activity, the timing of pregnancy, and health behaviors during pregnancy (Cohen et al., 2007), leading to improved birth outcomes. Specific pathways through which PRS influence LBW risk and other adverse birth outcomes is an important topic for future research.

We also found some preliminary evidence that increasing local government expenditures on HCD is associated with reduced incidence of LBW. This association was only significant at $p < .10$, with the magnitude being approximately one-third of the PRS effect (although it was significant when the effect was estimated individually). Our findings therefore resemble research showing that increases in county government expenditures on HCD are associated with improvements in county health rankings (McCullough & Leider, 2016). Voluminous research exists documenting the health benefits of stable and safe housing (Burgard, Seefeldt, & Zelner, 2012; Carrion et al., 2015), as well as benefits of residence in communities characterized by high social cohesion and perceived safety (Srinivasan, O'Fallon, & Dearry, 2003). Research is sorely needed, however, into different types of local government HCD programs as they relate to human health. Providing housing vouchers to assist with relocation from public housing, investing in disadvantaged communities, and equitable zoning policies are a few potential strategies that could be employed by local governments, which have been found to have positive health benefits (Maantay, 2001; Sanbonmatsu et al., 2011; Wolch, Byrne, & Newell, 2014), even if gains to maternal and infant health are not understood.

The impact of local government health expenditures was not a primary focus of the current study, yet the reported findings on this topic warrant discussion. Higher health expenditures in the prior period were associated with a shrinking racial gap in LBW and VLBW incidence over a five-to-seven-year period. Thus, increasing local government health expenditures may help attain greater area-level equity in health. Prior research on the link between local health department spending and black-white disparities in adverse birth outcomes has been inconclusive. Specifically, findings suggest that health expenditures may reduce infant mortality to a greater degree among black relative to white infants (Grembowski et al., 2010), and that counties providing family planning, prenatal care, and nutritional assistance services marginally reduced their black-white infant mortality gap over time relative to counties without these services (Bekemeier et al., 2011); however, neither of these prior findings was statistically significant. Moreover, health expenditures in the present study were not significantly associated with reduced county incidence of LBW, but findings were in the expected direction with a *p*-value of approximately .10. Although spending on maternal health programs likely has a larger impact on birth outcomes relative to our broad measure of total health spending (Bekemeier et al., 2014), total health department spending has also been linked with lower rates of LBW and infant mortality (Bekemeier et al., 2014; Grembowski et al., 2010). Our findings are broadly consistent with this research and extend these findings to a substantially larger sample of counties and across multiple periods. Additional research is needed to identify effective programs for local health departments to improve birth outcomes while reducing associated racial disparities, yet our findings demonstrate the importance of public health expenditures.

Three strengths of the current study can be noted. First, the analytic sample includes a large cross-section of counties with multiple waves of data, allowing for the modeling of within county effects. This methodological approach limited potential confounding influences and strengthened our ability to make causal inference. Second, to our knowledge, we are the first to estimate the association between local government expenditures on HCD or PRS and adverse birth outcomes. Furthermore, we included a specific focus on county black-white disparities in LBW incidence, a topic that is of high relevance to our national health priorities and many scientific disciplines. Lastly, examining a relatively common outcome (i.e., LBW) with a large sample of birth records—including approximately one-half of all births during study periods—allowed for reliable county estimates of birth outcomes over time. Similar modeling strategies can be used in future research to investigate policy and ecological influences on health.

A limitation to the present research is our inability to consider how resources are spatially distributed within areas or to examine specific programs offered as they relate to the umbrella categories of HCD and PRS. The extent to which services are inequitably distributed would limit the potential of increases in services to reduce health disparities. For example, an analysis of parks in Los Angeles indicated that neighborhoods with predominant ethnic minority populations had fewer parks despite being more densely populated, and that new parks often served to exacerbate existing inequities in park access (Wolch, Wilson, & Fehrenbach, 2005). Separate from physical proximity, access to parks is also often limited in less affluent or ethnic minority communities because available parks are less aesthetically pleasing or have surrounding noxious characteristics (Franzini et al., 2010; Taylor et al., 2007). Identifying the practices of local governments that are successful in promoting health via increasing PRS, especially for disadvantaged communities with elevated health risks, is a key objective for future research.

Similarly, rather than considering overall HCD spending, it is important that the health influence of specific HCD programs is investigated. For example, the provision of housing assistance could be through public housing opportunities—often situated in high poverty, spatially disconnected communities—or it could be through housing vouchers that allow for movement into mixed income communities with a greater supply of economic and educational resources (Sanbonmatsu et al., 2011). Examples abound of marginalized populations being displaced as a result of urban redevelopment or of investments benefiting suburban communities at the expense of densely populated urban centers where a disproportionate share of people of color reside (Goetz, 2011; Thomas, 2013). HOPE VI is one example of a federal grant program that has received pointed criticism for potentially harming the health and well-being of public housing residents; the charge being that the revitalization of public housing projects often led to the displacement of poor residents and the disruption of their communities in favor of attracting affluent residents and private investment (Keene & Geronimus, 2011). Examination of the health implications of specific local government programs relating to HCD is needed.

Another limitation of the present study is that our modeling strategy did not allow for the investigation of between county differences in hypothesized associations. Additional research will be valuable in elucidating how local government features and the profile of socioeconomic characteristics of residents influence government spending patterns and the resulting population health impacts. We preferred to focus on within county variance over time as area characteristics are often highly collinear, introducing the potential for multiple confounders and limiting the reliability of estimated associations (Morgenstern, 1995). Controlling for stable county characteristics through fixed effects models reduced the possibility of omitted variable bias being introduced into the model. Although we attempted to adjust for time-varying confounders in the link between expenditures on HCD and PRS and incidence of LBW, we cannot rule out that the possibility that important variables were unintentionally excluded from analytic models.

In conclusion, the health implications of local government practices and policies are infrequently the focus of scientific inquiry, especially when compared to state and national policies. The role of county governments as service providers, however, is generally expanding and with this elevated responsibility should come expectations for improvements to human health, particularly among disadvantaged segments of their populations. The current study finds evidence that increases in local government expenditures on PRS has likely had a positive impact on LBW incidence, independent of changes in total spending and other health-relevant services. If confirmed by future research, increasing PRS represents a policy that can be used to improve birth outcomes. Given that reducing LBW incidence would also reduce many societal costs that stem from LBW with the potential for national externalities (Almond, Chay, & Lee, 2005; Petrou, Sach, & Davidson, 2001), there is a need for state and federal grants to support communities that lack sufficient PRS, grant funding that is currently very limited. Factoring in the indirect population health gains of PRS alongside other effects that are often of primary interest (i.e., increasing exercise, reducing obesity risk) presents a more accurate picture of the potential benefits and could increase the public appetite for such services.

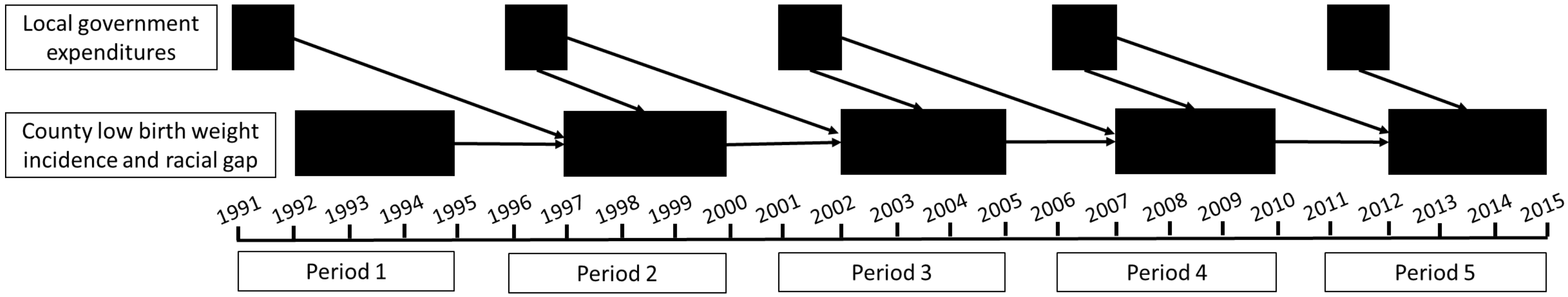

Figure 1. Timeline of measurement occasions for local government expenditures and low birth weight outcomes, with arrows indicating modeled associations.

Table 1. Descriptive statistics for 956 United States counties during five separate periods, spanning from 1992 to 2014.

Variables	Period 1 M ±SD	Period 2 M ±SD	Period 3 M ±SD	Period 4 M ±SD	Period 5 M ±SD
Local government expenditures ($100s per capita, 2012 dollars)					
Total operational	27.04 ±9.45	28.91 ±9.55	32.99 ±11.24	36.72 ±13.12	36.04 ±12.44
Housing and community development	0.43 ±0.50	0.51 ±0.53	0.63 ±0.63	0.70 ±0.67	0.74 ±0.70
Parks and recreation	0.38 ±0.37	0.41 ±0.38	0.50 ±0.43	0.55 ±0.49	0.53 ±0.44
Health	0.63 ±0.69	0.75 ±0.97	0.86 ±1.08	0.92 ±1.10	0.91 ±1.10
Hospital	2.34 ±3.98	2.26 ±4.37	2.36 ±5.03	2.54 ±5.49	2.73 ±5.81
Total population (in tens of thousands)	20.25 ±45.68	21.49 ±47.74	22.66 ±50.07	23.80 ±51.32	24.90 ±53.68
Black density (%)	19.81 ±15.17	20.20 ±15.41	20.00 ±15.42	20.19 ±15.46	20.23 ±15.41
Median income ($1000s, 2012 dollars)	47.20 ±13.00	50.62 ±13.48	48.97 ±13.86	49.62 ±14.48	46.69 ±13.78
Low birth weight (per 100 births)	6.85 ±1.80	7.05 ±1.77	7.45 ±1.97	7.70 ±2.10	7.41 ±2.00
Racial gap in low birth weight (per 100 births)	6.08 ±2.47	5.90 ±2.17	6.18 ±2.21	6.02 ±2.21	5.82 ±2.43

Note. Periods 1 through 5 correspond to: 1992-1994; 1997-1999; 2002-2004; 2007-2009; 2012-2014. Local government expenditures approximately correspond to the fiscal year immediately preceding each period. Data for each period represent all 956 counties in the analytic sample.

Table 2. Estimates from bias corrected fixed effects models indicating the influence of local government expenditures on changes in county low birth weight incidence *(N* = 956 counties for a total of 3619 observations).

	Model 1		Model 2		Model 3	
	Estimate	[95% CI]	Estimate	[95% CI]	Estimate	[95% CI]
Low birth weight$_{(t\text{-}1)}$ (1/100 live births)	**.33**	**[.25, .41]**	**.33**	**[.25, .41]**	.27	[.19, .35]
Local government expenditures (Δ $100 per capita)						
Total operational	.00	[-.02, .01]	.00	[-.02, .01]	.00	[-.02, .01]
Housing and community development	-.08	[-.20, .03]	-.09	[-.20, .02]	-.09	[-.20, .01]
Parks and recreation	**-.25**	**[-.44, -.06]**	**-.26**	**[-.44, -.08]**	**-.25**	**[-.42, -.07]**
Health	-.05	[-.10, .01]	-.05	[-.11, .01]	-.04	[-.09, .01]
Hospitals	.01	[-.01, .03]	.01	[-.01, .03]	.01	[-.01, .04]
Local government expenditures$_{(t\text{-}1)}$ (Δ $100 per capita)						
Total operational$_{(t\text{-}1)}$			.01	[-.01, .02]	.01	[-.01, .02]
Housing and community development$_{(t\text{-}1)}$			-.01	[-.12, .10]	-.01	[-.12, .09]
Parks and recreation$_{(t\text{-}1)}$			-.02	[-.21, .18]	-.03	[-.20, .14]
Health$_{(t\text{-}1)}$			-.04	[-.10, .03]	-.03	[-.09, .03]
Hospitals$_{(t\text{-}1)}$			-.01	[-.04, .01]	-.01	[-.03, .01]
Demographic and economic covariates						
Median household income ($10,000)					**-.14**	**[-.26, -.03]**
Black density (10%)					**.70**	**[.46, .94]**
Population change (10%)					**-.16**	**[-.26, -.05]**

Note. Estimates in bold are significant at p <.05. Period fixed effects are included in all models.

Table 3. Estimates from bias corrected fixed effects models indicating the influence of local government expenditures on changes in county black-white differences in low birth weight (LBW) incidence (*N* = 956 counties for a total of 3619 observations).

	Model 4		Model 5		Model 6	
	Estimate	[95% CI]	Estimate	[95% CI]	Estimate	[95% CI]
Racial gap in LBW$_{(t\text{-}1)}$ (1/100 live births)	**.15**	**[.09, .21]**	**.15**	**[.08, .21]**	**.14**	**[.08, .20]**
Local government expenditures (Δ $100 per capita)						
Total operational	-.01	[-.04, .02]	-.01	[-.03, .02]	-.01	[-.03, .02]
Housing and community development	-.06	[.32, .21]	-.03	[-.29, .22]	-.03	[-.29, .22]
Parks and recreation	-.23	[-.74, .28]	-.23	[-.74, .28]	-.21	[-.76, .34]
Health	.04	[-.11, .18]	.02	[-.12, .16]	.02	[-.13, .16]
Hospitals	.03	[-.02, .08]	.03	[-.02, .03]	.03	[-.02, .08]
Local government expenditures$_{(t\text{-}1)}$ (Δ $100 per capita)						
Total operational$_{(t\text{-}1)}$			-.01	[-.04, .01]	-.01	[-.03, .02]
Housing and community development$_{(t\text{-}1)}$			.04	[-.25, .33]	.05	[-.27, .36]
Parks and recreation$_{(t\text{-}1)}$			-.05	[-.55, .44]	-.02	[-.53, .49]
Health$_{(t\text{-}1)}$			**-.29**	**[-.44, -.14]**	**-.30**	**[-.47, -.12]**
Hospitals$_{(t\text{-}1)}$			.01	[-03, .05]	.00	[-.04, .04]
Demographic and economic covariates						
Median household income ($10,000)					-.27	[-.57, .03]
Black density (10%)					-.36	[-.79, .06]
Population change (10%)					**-.25**	**[-.50, -.01]**

Note. Estimates in bold are significant at p <.05. Period fixed effects are included in all models.

Study 2 – Fluctuations in County Median Income are Associated with Low Birth Weight Incidence and Black-White Disparities

Abstract

Infants born with a low birth weight (LBW) are at increased risk of infant mortality, developmental delays, and adulthood morbidity. That LBW incidence varies substantially across places and between racial/ethnic groups is therefore a major public health issue in the United States. The current study examines within county fluctuations in median household income and black-white differences in income as predictors of LBW incidence and the black-white LBW gap. Data on birth weight and maternal factors from approximately 24.8 million singleton births to non-Hispanic black or white mothers were aggregated by county and three-year periods, spanning from 1992-2014. Two sets of covariates representing maternal sociodemographic (education, nonmarital childbearing, and age) and health risks (smoking during pregnancy, insufficient weight gain, and inadequate prenatal care) were examined as potential explanations of county income effects on LBW. A total of 732 counties had 20 LBW cases for each racial group in at least two periods and had data for substantive predictors, making an analytic sample of 2798 county-by-period observations. Using county by period fixed effects models, a $5,000 increase in county median income was associated with a reduction in LBW incidence of 1.3 births per 1000, and in the black-white LBW gap by 2.8 births per 1000. Adjusting for fluctuations in county maternal sociodemographic and health risks attenuated the inter-temporal link between median income and LBW incidence by 72% and 31%, respectively. The

association between median income and the black-white LBW gap was largely unexplained by racial differences in maternal sociodemographic and health risks, suggesting that other factors need to be considered (e.g., community resources). Improving economic opportunities and the availability of well-paying employment may be important paths for reducing geographic and racial disparities in LBW incidence.

The United States federal government, as well as many state and local governments, are committed to reducing infant mortality and associated determinants (e.g., low birth weight), particularly among groups with elevated risk (Healthy People 2020, 2010). The tremendous variation in adverse birth outcomes existing between counties and cities suggests that health initiatives should target risks within local contexts (Kramer & Hogue, 2008; Thompson et al., 2005). For example, in one study, low birth weight (LBW; <2500 g.) incidence ranged from 3.8 to 10.6 cases per 100 live births between Neonatal Intensive Care Regions (i.e., multi-county areas)—differences that were due, in part, to area variation in household income levels and behavioral health risks (Thompson et al., 2005). Disparities in adverse birth outcomes between black or African American and white infants also show spatial variation (Rossen et al., 2016), with the black-white relative infant mortality rate ranging from 1.5 to 4.8 between counties.

Understanding the social and geographic patterning of LBW has implications for lifelong group disparities in health and well-being. Specifically, beyond the tragedy of infant mortality, infants born LBW—particularly at the smaller end of the weight distribution—are also at higher risk of impaired cognitive functioning, low academic achievement, and cardiovascular disease (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Barker, 2006). The current study makes two primary contributions to the literature on area effects and social determinants of birth outcomes by examining 1) within county fluctuations in median income as a predictor of LBW incidence; and 2) within county fluctuations in median income and black-white differences in income as predictors of the black-white gap in LBW. Potential explanations for the income effects on LBW outcomes are also considered (namely, maternal sociodemographic and health risks). Elucidating determinants of county incidence of adverse birth outcomes is an important step in understanding the development of spatial variation, and in public health surveillance and preventive efforts.

County Income Distributions and Birth Outcomes

The affluence of residents is one key contributor to the wide differences between counties in LBW incidence and infant mortality. Prior research has indicated, using an aggregate measure of socioeconomic deprivation, that the least advantaged quintile of counties had between 40-60% higher infant mortality in recent decades relative to the most advantaged quintile (Singh & Kogan, 2007). Moreover, the substantial gap in infant mortality and incidence of LBW between counties has also been described as a function of median household income (Krieger et al., 2008; Thompson et al., 2005), with evidence that median income is an especially valuable predictor of area-level birth outcomes (Siddiqi et al., 2016). Despite established benefits of county-level economic resources, no prior research, to our knowledge, has considered the effects of within county changes in household economic characteristics on birth outcomes.

Substantial heterogeneity in birth outcomes also exists *within* counties, often as a function of place, economic factors, or race/ethnicity. Black infants, for instance, have elevated rates of LBW and premature births relative to whites in all cities and multi-county areas in the U.S. (Kramer & Hogue, 2008; Thompson et al., 2005). Yet, racial differences are also place-specific. For instance, black-white infant mortality ratios range from 1.6 to 3.3 between states (Mathews & MacDorman, 2013b), and this state variation is partially explained by state black-white differences in education and unemployment (Wallace, Crear-Perry, Richardson, Tarver, & Theall, 2017). No prior research, however, has examined determinants of county variation in the magnitude of racial differences in adverse birth outcomes. The utility of such a methodological approach was demonstrated by cross-sectional research on the black-white gap in premature mortality, with findings indicating substantial variation between counties that stemmed from black-white differences in social and economic determinants (Cullen, Cummins, & Fuchs, 2012). County differences in life expectancy between black and white Americans and by income quartile also appear to be smaller in areas with higher median income (Chetty et al., 2016; Cullen et al., 2012). Thus, county-level black-white differences in economic resources may contribute to county variation in racial disparities in LBW, yet additional research is needed to examine longitudinal evidence and model black-white disparities in adverse birth outcomes.

Social and Health Processes Underlying Income Effects

Due to moderate to high correlations between an array of area-level social and economic indicators of advantage (Cullen et al., 2012; Dwyer-Lindgren et al., 2017), prior research has not disentangled predominant area predictors of adverse birth outcomes. Specifically, counties with high median income also generally have high average levels of educational attainment, social capital, and other family resources, while attracting greater private investment in businesses, in-migration of skilled works, and other community resources (Glaeser & Saiz, 2003; Rupasingha, Goetz, & Freshwater, 2006; Singh & Kogan, 2007). One limitation of research examining geographic disparities in adverse birth outcomes has therefore been a reliance on cross-sectional data where such collinearity is more pronounced (Blumenshine et al., 2010; Krieger et al., 2008; Singh & Kogan, 2007). As a result, explanations of the underlying socioeconomic processes that lead to geographic disparities are prone to being confounded by third variable explanations.

Two broad factors may account for a portion of the link between county median income and LBW incidence—namely, maternal sociodemographic characteristics and maternal health status or resources. In particular, economically disadvantaged areas (i.e., those with low median income or high unemployment) have a higher prevalence of nonmarital childbearing, teenage pregnancy, and births to mothers without a high school education (Romero, 2016; Shattuck & Kreider, 2008; Wertheimer, Jager, & Moore, 2000). Each of these maternal characteristics has been consistently linked with elevated LBW risk (Chen et al., 2007; Mathews & MacDorman, 2013b; Raatikainen, Heiskanen, & Heinonen, 2005; Yang, Shoff, & Matthews, 2013). Moreover, fertility patterns within population groups (e.g., among mothers with low educational attainment) could be differentially influenced by economic optimism and opportunities, such that the socioeconomic risk profiles of birthing mothers (i.e., education level, marital status, age) and their partners covary with economic cycles (Colen, Geronimus, & Phipps, 2006). For example, black teenagers (but not white) have been found to delay childbearing as a result of increased employment opportunities (Colen, Geronimus, & Phipps, 2006). Thus, the link between changes in county median income and area-level birth outcomes may arise from changes to the sociodemographic risk profiles of mothers.

Substantial black-white differences in maternal education, nonmarital childbearing, and teenage pregnancy are also present, potentially contributing to racial differences in birth outcomes. However, black-white disparities in LBW risk generally exist independent of racial differences in maternal-level education, marital status, and teenage pregnancy (Bennett, 1992; DuPlessis, Bell, & Richards, 1997; Jaffee & Perloff, 2003). Even so, considered as area-level prevalence estimates, black-white differences in education, nonmarital childbearing, and teenage pregnancy may serve as proxies for unequal access to community resources, residential segregation, crime exposure, mass incarceration, and other indicators of socioeconomic disadvantage (Carlson, McNulty, Bellair, & Watts, 2014; Charles & Luoh, 2010; Chetty, Hendren, Jones, & Porter, 2018; Wilson, 2012). Racial differences in nonmarital childbearing and teen pregnancy have also decreased in recent decades, trends that have the potential to influence black-white disparities in birth outcomes (Romero, 2016; Sweeney & Raley, 2014).

The second potential explanation for the effects of rising median income on declining LBW incidence is via reduced maternal health risks. Although maternal health influences on fetal growth and premature birth are myriad (Kramer et al., 2000), smoking during pregnancy, nutrition, and prenatal care are three health risks that are influenced by local economic contexts. Specifically, area-level economic disadvantage has been linked with higher prevalence of maternal smoking during pregnancy, insufficient gestational weight gain, and inadequate prenatal care (DeFranco, Lian, Muglia, & Schootman, 2008; Messer et al., 2012; Vinikoor-Imler, Messer, Evenson, & Laraia, 2011). Although one prior study tested maternal health risks as explanations for county economic effects on preterm birth (DeFranco et al., 2008)—finding little support for inadequate prenatal care or maternal smoking beyond individual demographic variables—additional research is needed to examine maternal health risks as explanations for the association between area-level economic conditions and LBW incidence.

Black-white differences in insufficient gestational weight gain and inadequate prenatal care are substantial (Gadson, Akpovi, & Mehta, 2017; Leonard et al., 2017). The presence of geographic variations in the magnitude of disparities in these risks may suggest differences in area-level resources or environments that encourage physical activity and diet, and differential access to health care or health services (Laraia, Messer, Evenson, & Kaufman, 2007; Rossin-Slater, 2013; Tabet, Nelson, Schootman, Chien, & Chang, 2017). Yet no prior research has focused on area-level black-white disparities in either insufficient gestational weight gain or inadequate prenatal care (for an example in the American Indian population, see Johnson, Call, & Blewett, 2010). With regards to maternal smoking, black mothers are less likely to smoke during pregnancy relative to whites (Ventura, Hamilton, Mathews, & Chandra, 2003). However, differences in smoking rates for black and white women vary by state and race-specific patterns of geographic variations in maternal smoking are largely independent from each other (Osypuk, Kawachi, Subramanian, & Acevedo-Garcia, 2006).

Current study

The primary aims of the current study are twofold. First, the association between within county fluctuations in median household income and LBW incidence was estimated. Second, within county fluctuations in median income and racial income differences were examined as predictors of black-white disparities in LBW. Although state-level median income increases are associated with reduced infant mortality and smaller black-white disparities within states (Siddiqi et al., 2016), the present study is the first to our knowledge to estimate inter-temporal links between county economic characteristics and adverse birth outcomes. The focus on race-specific median income and county black-white disparities is particularly novel, with the potential to elucidate local economic, social, and health determinants of racial disparities in LBW. As exploratory hypotheses, two sets of covariates were considered that may explain the link between county income distributions and LBW outcomes: 1) maternal sociodemographic risks (low maternal education, nonmarital childbearing, and maternal age); and 2) maternal health risks (i.e., smoking during pregnancy, insufficient gestational weight gain, and inadequate prenatal care).

The current study capitalized on data from multiple sources from 1992 through 2014, and included nearly two-fifths of all births in the U.S. during the study periods. Using county by period fixed effects models, the analyses tested the following hypotheses:

H_1: Fluctuations in county median household income are inversely associated with low birth weight incidence, such that rising median income corresponds to reduced LBW incidence.

H_2: Fluctuations in county median household income are inversely associated with black-white disparities in LBW, such that rising median income is linked with a smaller LBW disparity.

H_3: Fluctuations in black-white median income differences are inversely associated with black-white disparities in LBW, such that a shrinking income gap is linked with a smaller LBW disparity.

Methods

Data

To examine study hypotheses, data were derived from multiple publicly available and restricted access sources. National birth records from 1992 to 2014, initially collected through the National Vital Statistics System, were obtained through the National Center for Health Statistics with county identifiers (Federal Information Processing Standards codes). More than 99% of all births occurring in the US were included (Schoendorf & Branum, 2006), representing approximately 4 million births per year. Because of our focus on black-white differences in LBW rates, only singleton births to non-Hispanic black or non-Hispanic white mothers were included in the present analytic sample (41.02 of 60.68 million births). Individual birth records were aggregated to the county level—including race-specific estimates—and pooled over three-year periods to indicate the incidence of LBW and prevalence of maternal risks per 100 live births. Assessment periods are shown in Figure 1 and correspond to available data on county income estimates, with some years omitted to increase period-to-period variability and because of limited data availability for race-specific median income estimates. For each period in the analytic sample, counties were required to have at least twenty cases of LBW for each racial group, leading to the exclusion of 11,527 county-by-period measurements. This cutoff was selected to increase the reliability of multiple variables, including county-level estimates of LBW, maternal sociodemographic characteristics, and maternal health risks. The practical effect was that all counties in the sample had more than 100 births to black mothers for each period (and nearly 300 births to white mothers).

County FIPS codes were used to merge aggregated birth records data with county variables. In particular, annual estimates of county median household income were obtained through the U.S. Census Bureau's Small Area Income and Poverty Estimates program, whereas race-specific median household income estimates came from the Decennial Censuses and American Community Surveys. Where possible, three-year averages of median household income were examined to minimize the influence of error in income estimates. Annual county population estimates by racial group were obtained through the Census Bureau Housing Unit and Population Estimates program.

Counties were excluded that had missing data for racial income differences (317 county-by-period measurements), high percentage of missing data for individual maternal health risk factors (396 county-by-period measurements), and less than two periods (82 county-by-period measurements). Sample criteria resulted in 732 counties with a total of 2798 observations. Because of the bias toward inclusion of large counties, these observations still represent data from 24.76 of the 42.0 million singleton births to non-Hispanic black (6.76 million births) and non-Hispanic white (18.00) mothers that occurred during study periods. Models were also fit using less restrictive inclusion criteria: in the case of LBW incidence (all counties with at least ten cases of LBW); in the case of the black-white LBW gap (all counties with ten cases of LBW for each racial group and data for racial income differences). The same pattern of findings concerning the estimated associations between fluctuations in county median income and LBW outcomes was detected, and therefore we report results from our preferred models.

Measures

Birth records. Maternal and infant factors were assessed from birth records. For each variable specified below, the prevalence of mothers endorsing the criterion within each county during three-year measurement occasions was coded. Race-specific county prevalence estimates were coded using the maternal racial classifications of non-Hispanic black and non-Hispanic white, from which the absolute gap between black and white mothers or infants was derived.

Birth weight. Birth weight is directly assessed and reliably recorded on birth records (Northam & Knapp, 2006). Birth weights of less than 2500 grams were coded as LBW. The county incidence of LBW was then computed during each period as the number of LBW cases divided by the total number with birth weight data (99.9% of record included birth weights). The racial gap in LBW is represented by the absolute difference in county-specific LBW rates for black and white infants. In addition, county incidence of very low birth weight (<1500 g.) and the black-white gap in very low birth weight incidence were coded for supplemental analyses.

Sociodemographic characteristics. Birth records contain limited information on family socioeconomic factors, with maternal education being the only variable that is consistently available (Singh & Kogan, 2007). To ensure conformity across data periods, prevalence of low maternal educational attainment was coded as percent obtaining high school diploma or less. Marital status at time of birth (married, unmarried) was coded as prevalence of nonmarital childbearing (Osterman et al., 2015). Maternal age was coded to represent the prevalence of teenage pregnancy (age $\leq$ 18 y.) and advanced maternal age pregnancy (age $\geq$ 35 y.) (Fall et al., 2015). Prevalence of advanced age pregnancies was included because it has been linked with reduced risk of intrauterine fetal growth restriction, but not premature births (i.e., the two causal determinants of LBW), and is more common among socioeconomically advantaged mothers (Kenny et al., 2013).

Maternal health characteristics. Maternal smoking or tobacco use during pregnancy was coded as a dichotomous variable (yes/no) and aggregated to the county prevalence (Ventura et al., 2003). Gestational weight gain recommendations are based on pre-pregnancy weight status (Institute of Medicine, 2010), yet pre-pregnancy maternal weight was not available for the majority of years. Thus, a conservative cutoff for insufficient gestational weight gain was selected using the IOM recommendations for overweight women adjusted for gestational length; less than 15 lbs or the equivalent of gaining less than .484 lbs/week after week 9 of gestation (per CDC weight gain by gestational age charts; CDC, 2016). Prior research has successfully considered the fetal effects of insufficient gestational weight gain without consideration of maternal pre-pregnancy weight status (Davis & Hofferth, 2012). Using the Adequacy of Prenatal Care Utilization Index (Kotelchuck, 1994), prevalence of inadequate prenatal care was coded if prenatal care was initiated after 4 months or if fewer than 50% of recommended visits were received based on gestational age at birth.

County sociodemographic characteristics. County median household income was estimated by the Census Bureau using data from administrative tax records, government transfers, decennial Census statistics, and the Current Population Survey or American Community Survey (Bell et al., 2007), with the following available years included: 1993, 1997-1999, 2002-2004, 2007-2009, and 2012-2014. Race-specific county median household income estimates were measured for black and white households during the 1990 and 2000 Decennial Censuses, and via the American Community Survey using 2005, 2007-2009 three-year estimate, and 2012-2014 waves. Estimates for 1992 and 1998 median income for black and white households were then derived from 1990 and 2000 Censuses as weighted averages, and for 1993 from the 2000 Census and 2005 American Community Survey. Due to high missing data for one-year estimates in 2012-20014 (three-year estimates were not released this year), missing data values were imputed using the 2011-2013 three-year estimate. The racial income gap was computed at each period as the absolute difference between black and white households. All income estimates were adjusted to 2015 dollars using the Consumer Price Index. Note that median income estimates from the American Community Survey are based on reports of household income in the last 12 months that were collected throughout the year, such that estimates encapsulate a period of 23 months (depending on the date of the interview). Figure 1 therefore refers to approximate years.

Population estimates by racial group are publicly available as intercensal and postcensal estimates, and the midpoint of each period was selected: 1993, 1998, 2003, 2008, and 2013. Black density was coded as the percent of total county residents categorized as non-Hispanic black. Population change between periods was measured as: (total $\text{population}_{(\text{period})}$ - total $\text{population}_{(\text{period - 1})}$) / total $\text{population}_{(\text{period - 1})}$. Total population in 1988 was used to compute population change for 1993.

Plan of Analysis

Univariate descriptive statistics are reported separately for black and white county residents or mothers. Correlations in which time and county fixed effects were residualized from all study variables are shown, indicating within county relationships irrespective of national secular time trends. Given the scarcity of prior research depicting county variation in birth outcomes, we mapped LBW incidence per 100 births and the black-white difference in LBW across the study periods for all counties that had at least 30 LBW births for both black and white infants. The maptile program in Stata was used to visualize county LBW data (Stepner, 2017). Next, we utilized county by period fixed effect linear regression models to test hypothesized associations. Such models remove all variance that is due to time-invariant between county differences—in effect, considering each county as its own control. Specifically, the fixed effect estimator county-mean centers all variables in the model. Time fixed effects are also essential due to secular changes that have influenced national LBW rates as well as many other predictors (e.g., maternal smoking, and nonmarital childbearing). Models were estimated using the xtreg command with the fe vce(robust) options in Stata 14.2. The option vce(robust) uses the Huber/White sandwich estimator to report standard errors that are robust to serial correlation and heteroskedasticity (Stock & Watson, 2008).

A series of models was conducted for each LBW outcome (county incidence of LBW per 100 births, and the black-white gap in LBW). First, the association between within county fluctuations in median income and fluctuations in county LBW incidence was estimated after adjusting for county and time fixed effects, and time-varying black density and population change (Model 1a). Specifically, the following model was fit:

$$Y_{ti} = a_i + b_1 income_{ti} + \beta_2 x_{ti} + \beta_3 period + e_{ti}$$

where Y_{ti} refers to LBW incidence at period t in county i; a_i is the time-invariant county effect; b_1 refers to the coefficient representing the magnitude of the association between fluctuations in median household income and LBW incidence; $\beta_2 x_{ti}$ is the vector of time-varying covariates; $\beta_3 period$ is a vector representing period dummy variables; and e_{ti} is the error for period t in county i.

The following blocks of covariates were then added independently as explanations for the inter-temporal link between county median income and LBW incidence: low maternal education, nonmarital childbearing, teenage pregnancy, and advanced age pregnancy (Model 1b); and maternal smoking during pregnancy, insufficient gestational weight gain, and inadequate prenatal care (Model 1c). A final model was then fit in which both explanatory blocks were considered simultaneously (Model 1d).

When county black-white differences in LBW were modeled as the outcome, a similar progression of models was followed as described above. In particular, after adjusting for county and time fixed effects, and time-varying black density and population change, the main effect of fluctuations in county median household income on fluctuations in the racial LBW gap was estimated (Model 2a). Fluctuations in the black-white difference in median household income was added in Model 2b. The explanatory blocks of time-varying covariates were then added: adjusting for fluctuations in county black-white differences in prevalence of low maternal education, nonmarital childbearing, teenage pregnancy, and advanced age pregnancy (Model 2c); and maternal smoking during pregnancy, insufficient gestational weight gain, and inadequate prenatal care (Model 2d). All covariates were then considered simultaneously (Model 2e).

Supplemental models were also conducted in which county very low birth weight (VLBW) incidence and the county black-white VLBW gap were examined as the outcome in models that paralleled those described for LBW outcomes. The advantage of modeling VLBW is that birth weight is a nonlinear risk factor for infant mortality and long-term developmental outcomes, such that risk increases dramatically with VLBW relative to moderate low birth weight (Boardman et al., 2002; Wise, 1993). Alternative specifications were also implemented to consider the possibility that the link between fluctuations in median income and LBW outcomes is due to high in-migration into affluent counties by adults with high human capital or out-migration by skilled workers from disadvantaged counties. Data were not available on duration of residency in counties for birthing mothers, and so we modeled change in total population from 1993 to 2013 as a between county predictor, and we adjusted for the county-mean across study periods of median income, black density, and total population (logged). Two-level mixed effects models were fit using the Stata xtmixed command with the vce(robust) option. Level 1 variables were county-mean centered to estimate within county effects.

Results

Counties in the analytic sample were primarily located in rural areas in the Southeast and in metropolitan areas across the United States. Averaged across study periods, the mean county population was nearly 300,000 (SD = 567,116) with a range of approximately 18,000 to 9.6 million. On average, 19.7 percent of county residents were characterized as non-Hispanic black (SD = 14.7; range from 1.2 to 77.8%). County median household income also had substantial variation (mean = \$51,971, SD = \$14,056; range from \$28,281 to \$113,551). Additional descriptives for sample counties are averaged across periods and shown separately for white and black mothers in Table 1. Paired sample t-tests indicate significant differences for black and white residents or mothers for each study variable at $p < .001$. Bivariate correlations between primary study variables are shown in Table 2 in which county and time fixed effects are residualized, and thus indicate within county inter-temporal links. Correlations were generally consistent with hypothesized relationships—the exception being that the black-white income gap was inversely correlated, albeit weakly, with the racial gap in LBW ($r = -.07$). As a comparison, and to demonstrate potential problems of multicollinearity when examining between county differences, Table S3 in appendices depicts a correlation matrix using county mean variables.

One observation is that black-white differences in income and LBW are directly correlated (*r* = .29). All between county correlations were consistent with hypothesized relationships.

Graphical representations of county-specific LBW incidence per 100 births and the black-white gap in LBW are shown in appendices as Figures S3 and S4. Note that all counties with 30 or more cases of LBW for each racial group across study periods are depicted (*n* = 1182). Whereas LBW incidence appears particularly high among counties in the Southeast, counties with the highest quintile of racial disparities in LBW are more geographically dispersed.

Determinants of County Low Birth Weight Incidence

Full model results of within county fluctuations in LBW incidence as the outcome are depicted in Table 3. Model 1a indicates that, after adjusting for county and period fixed effects and time-varying black density and population change, fluctuations in median household income were inversely associated with LBW incidence. Specifically, a $5000 increase in median income was linked to 1.3 fewer cases of LBW per 1000 births. The magnitude of this effect is demonstrated using the metric of within county SD units for each variable, such that a 1 SD increase in income is linked with a .12 SD unit decrease in LBW (effect sizes using *within county SD units* are presented for all variables below).

Model 1b adjusted for fluctuations in prevalence of maternal sociodemographic risks (i.e., low maternal education, nonmarital childbearing, teenage pregnancy, and advanced pregnancy age). Notably, the inter-temporal association between median household income and LBW incidence was attenuated by 72% and became non-significant. Post-hoc estimation indicated that nonmarital childbearing was the key covariate, reducing the income – LBW association by 59% when other sociodemographic covariates were excluded. Model 1c was adjusted for fluctuations in prevalence of maternal health risks (i.e., maternal smoking, insufficient weight gain, and inadequate prenatal care), and the inter-temporal link between county median income and LBW incidence was attenuated by 31% but remained significant ($p < .001$). When all explanatory covariates were modeled simultaneously in Model 1d, the median income estimate was reduced by 83%.

Determinants of Racial Differences in Low Birth Weight Incidence

Models were also fit in which fluctuations in the black-white difference in LBW incidence was modeled as the outcome (see Table 4 for full set of models). All models adjusted for time and county fixed effects, as well as county fluctuations in black density and population change. Model 2a results indicated that fluctuations in median household income were associated with the black-white gap in LBW incidence. In particular, a $5,000 increase in median household income was associated with a reduction in the racial gap of 2.8 LBW cases per 1000 births. Stated differently, a within county 1 SD unit increase in median household income was linked with a reduction of .12 SD units in the racial LBW gap. Fluctuations in black-white differences in county median income was added in Model 2b. Contrary to hypotheses, an increase in the racial gap of $5,000 was associated with a decrease in the absolute black-white disparity in LBW incidence of 1.3 cases per 1000 births, and vice versa. A within county 1 SD unit increase in the racial income gap was linked with a .07 SD unit decrease in the racial LBW gap. In post-hoc models, fluctuations in county black median income and white median income were examined in place of county median income and the racial income gap. Results indicated that a $5,000 increase in white median income was estimated to reduce the black-white gap in LBW incidence by 2.4 cases per 1000 births ($p < .001$), whereas higher black median income was associated with a larger racial gap in LBW ($5,000 increase corresponding to larger gap of 1.1 per 1000 births, $p = .018$).

Models 2c and 2d were adjusted for county fluctuations in racial differences in sociodemographic characteristics and maternal health risks, respectively. Adjusting for time-varying racial differences in maternal sociodemographic risks attenuated the median income estimate by 12% but increased the racial income gap estimate by 25%. Accounting for maternal health risks reduced the racial income gap estimate by 17%. When all maternal covariates were adjusted simultaneously in Model 2e, the estimates for median income and black-white income differences were not substantively reduced.

Supplemental Models and Specification Tests

Supplemental analyses were conducted to model within county fluctuations in the incidence of very low birth weight (VLBW; <1500 g.) and the black-white gap in VLBW. Inclusion criteria were similar to prior models but counties were required to have at least 10 cases of VLBW incidence, leading to a smaller sample of 443 counties and 1708 observations. Study findings largely paralleled models considering LBW outcomes. In particular, fluctuations in median household income were associated with VLBW incidence ($5,000 increase was linked with .32 fewer cases per 1000 births, $p < .001$). This estimate was attenuated by 53% when adjusting for fluctuations in sociodemographic characteristics and 8% when adjusting for maternal health risks. A $5,000 increase in median household income was estimated to reduce the black-white gap by .71 cases per 1000 births ($p = .003$), while a $5,000 increase in the black-white income gap was estimated to reduce the black-white VLBW gap by .38 cases per 1000 births ($p = .032$). Fluctuations in county black-white differences in the prevalence of sociodemographic and maternal health risks only slightly attenuated estimates with income variables (by 20% or less).

Mixed effects models were fit to estimate within county effects of median income, adjusting for covariates included in Model 1a, population change (as a percentage) from 1993 to 2013, and county mean levels of total population (logged), black density, and median household income. The association between county fluctuations in median income and LBW incidence was comparable to Model 1a in Table 3 (Est. = -.28, 95% CI: -.38, -.18). Adjusting for maternal sociodemographic and health risks attenuated the within county effect of median income by 69% and 32%, respectively. When the black-white gap in LBW was modeled, estimates for within county fluctuations in median income (Est. = -.50, 95% CI: -.76, -.25) and racial income differences (Est. = -.30, 95% CI: -.46, -.14) were comparable to Model 2b, and blocks of covariates also explained a similar percentage of these estimates as did Models 2c and 2d.

Discussion

Reducing population incidence of low birth weight and decreasing the disproportionate burden of LBW experienced by black relative to white families are national priorities in the U.S. (Healthy People 2020, 2010; Martin et al., 2018). We find evidence to suggest that economic growth—measured as within county increases in median household income—may be one important approach to reduce LBW incidence and shrink the black-white disparity in LBW. Concordant findings for VLBW incidence demonstrate potential for increases in median income to manifest in other outcomes (e.g., reduced infant mortality, improved developmental outcomes) (Boardman et al., 2002; Wise, 1993). Specifically, a $5,000 increase in median income was estimated to decrease county incidence of LBW by 1.3 and VLBW by 0.3 per 1000 births; black-white differences in LBW and VLBW would also shrink by 2.8 and 0.7 cases per 1000 births, respectively. For reference, 2016 estimates of LBW and VLBW incidence per 1000 births are

64.4 and 10.8 per 1000 singleton births, with black-white absolute differences being 67.1 and 18.8 per 1000 live births, respectively (Martin et al., 2018).

Study findings are broadly consistent with voluminous research identifying benefits of economic resources for improving birth outcomes (Blumenshine et al., 2010; Singh & Kogan, 2007). For instance, cash transfers to low-income households (i.e., the earned income tax credit) reduces LBW incidence (Hoynes et al., 2015), and county median income is a strong predictor of infant mortality rates cross-sectionally (Krieger et al., 2008). That within-county population-level increases in median income predicted smaller black-white LBW disparities is also consistent with research indicating that growth in state median income led to declining black-white differences in infant mortality (Siddiqi et al., 2016), and that affluent counties have smaller disparities in life expectancy by race or income quintile (Chetty et al., 2016; Cullen et al., 2012). The present study is the first, however, to examine within county changes in household economic characteristics as a predictor of adverse birth outcomes and associated black-white disparities. The findings give credence to the notion that changes in county characteristics relating to material affluence may be direct precursors to changes in the distribution of birth outcomes.

Contrary to study hypotheses, we found that decreases in the black-white income gap were associated with a widening racial gap in LBW, and vice versa. This finding was due to LBW incidence among black infants decreasing more with positive fluctuations in median income among white relative to black county residents. Similarly, prior research has shown that within state increases in income inequality—likely corresponding to a widening racial income gap—are linked to declining racial disparities in infant mortality (Siddiqi et al., 2016). Another study found that black median income does not explain spatial variation in the rate of very premature births among black infants beyond overall median income (Kramer & Hogue, 2008).

In contrast, multiple cross-sectional findings indicate that areas with larger black-white economic inequities have wider racial health disparities (Cullen et al., 2012; Wallace et al., 2017), a finding present in our cross-sectional data as well. Research has also identified a weaker association between maternal economic factors and birth outcomes among black relative to white infants (Braveman et al., 2015; Colen, Geronimus, Bound, & James, 2006). These results suggest that, with respect to racial disparities in birth outcomes, the role of socioeconomic differences is complex and multifaceted and merits careful consideration (Colen, Geronimus, Bound, et al., 2006; Lu & Halfon, 2003).

Potential explanations for the inverse association between fluctuations in the racial gaps in income and LBW are 1) diminishing racial income differences could influence levels of interracial competition; 2) white median income is a better indicator of the economic well-being of counties relative to black median income, potentially due to the greater population size or relative power of white residents in many counties; or 3) findings were spurious due to error in black median household income estimates. Regarding the first explanation, experimental research in psychology has demonstrated that participants are prone to show out-group bias during times of economic scarcity by discriminating against and limiting resource allocation to black Americans (Krosch & Amodio, 2014; Krosch, Tyler, & Amodio, 2017). Supportive evidence also exists for the connection between economic conditions and reports of racial prejudice (Quillian, 1995). Heightened racial discrimination would then be a likely contributor to racial disparities in adverse birth outcomes (Giurgescu, McFarlin, Lomax, Craddock, & Albrecht, 2011). Support for the second explanation comes from research on the Great Recession illustrating that recovery has been slower in black relative to white communities (Kochhar & Fry, 2014), such that median income levels for whites may be more indicative of the availability of local economic resources. An affluent population base, in turn, appears to be health-promoting, potentially due to governments having a larger tax base to draw from with greater capacity to invest resources in public goods and social services (Chetty et al., 2016). Further evidence is needed to understand whether black Americans benefit from local economic upturns that increase community resources and optimism irrespective of economic gains within black communities. Thus, relative decline in economic position among whites could manifest in adverse health outcomes for people of color, even while racial economic differences wane. Finally, black median household income estimates do have wide margins of error, an issue we minimized by including three-year averages where possible. However, we do not believe this happens in a systematic way that would reverse the estimated coefficient. Also, county decreases in the racial income gap were related to smaller black-white differences in low maternal education and nonmarital childbearing, demonstrating that the racial income gap had meaningful predictive validity. Further research is needed with an explicit focus on changes in area-specific racial differences in economic conditions as influences on disparities in health.

Another key finding is that four-fifths of the link between fluctuations in county median income and LBW incidence was explained by maternal sociodemographic characteristics, with nonmarital childbearing being an especially important predictor. Although the link between nonmarital births and LBW status is established (Shah, Zao, & Ali, 2011), research on the effects of area-level economic conditions on nonmarital childbearing rates is inconclusive. On one hand, some evidence shows that nonmarital fertility is procyclical (i.e., decreasing during economic downturns). The period of the Great Recession through 2013 saw a substantial decline in nonmarital fertility that at times surpassed the concurrent decline in marital fertility, with the decline being most notable among states with high unemployment (Schneider & Gemmill, 2016).

Such a trend appears to be context-dependent, however, as annual state unemployment from 1975 to 1999 was not associated with nonmarital fertility rates (Dehejia & Lleras-Muney, 2004), and recent local economic booms increased marital and nonmarital fertility but not the share of nonmarital births (Kearney & Wilson, 2017). On the other hand, the link between area-level economic disadvantage and nonmarital childbearing rates is strong and established (Billy & Moore, 1992; Shattuck & Kreider, 2008), and the recent secular rise in nonmarital childbearing has been most pronounced among economically disadvantaged individuals (McLanahan & Jacobsen, 2015). Our study findings fit within the broader literature by demonstrating that nonmarital childbearing becomes a larger share of total county births when median income declines with implications for increasing LBW incidence. Inconsistent findings may be partly due to the use of median income rather than unemployment, the latter potentially having positive health sequelae and even reducing LBW incidence because of its transitory nature and increases in free time for health behaviors (Dehejia & Lleras-Muney, 2004; Ruhm, 2000). Additionally, our aim was to understand the influence of median income levels relative to a county baseline—rather than annual fluctuations—such that large decreases may reflect longer-term changes to local economies (e.g., substantial decrease in highly skilled employment). Modeling county rather than state outcomes also allows for greater movement between geographic units with the potential for selection by socioeconomic characteristics (i.e., out-migration of skilled workers; discussed as a limitation below). Thus, our findings have special relevance for potential processes underlying the development of spatial variation in adverse birth outcomes.

Despite strengths of the modeling approach (i.e., large number of counties with data over an extended time-period) and the novelty of study findings, important limitations exist. Aggregate data and other types of ecologic models have key limitations (Morgenstern, 1995), such as the inability to draw conclusions at the person level. The purpose of investigating maternal sociodemographic and health risks, however, was not to demonstrate their role as individual risk factors, but to consider their utility when measured at the area-level. County prevalence estimates indicate specific risk markers but also broad ecologic influences on these behaviors. For example, nonmarital childbearing rates potentially serve as a proxy for multiple contextual variables—levels of economic and health resources, social support and stress exposure, and norms around sexual behavior and family formation (Cairney, Boyle, Offord, & Racine, 2003; McLanahan, 2009; Putnam, 1995). For this reason, the estimates for individual maternal sociodemographic and health risks should be interpreted with caution and need to be considered in subsequent research with multilevel models. Local governments also have ready access to data from birth records and therefore demonstrating the utility of risk markers for LBW incidence has the potential to assist with health surveillance efforts and policy evaluation. Notwithstanding the limitations of aggregate data, examining within county fluctuations in study variables over multiple periods increases our confidence in estimated county-level effects.

An additional limitation is that county populations are not static over time. Estimates of the effects of median income changes do not disentangle contextual effects (i.e., improved local economic conditions) from compositional effects (i.e., in-migration of population with high social and economic capital). This limitation is of primary concern to the income-related estimates rather than maternal covariates, given that the latter are inherently compositional effects—that is, the expectation for elevated LBW incidence is explicitly due to the level of maternal health risks present among birthing mothers in the local population regardless of the duration of their residence within the county. Therefore, future research is needed to examine LBW incidence of long-term county residents as a function of changing county economic characteristics. Moreover, irrespective of whether contextual or compositional effects explain the link between shifts in median income and LBW incidence, the present findings demonstrate that county median income and maternal sociodemographic characteristics are likely contributors to the wide variation in LBW outcomes between counties.

Findings may also be unique to the historical period when data were collected. Prior research has indicated that fertility patterns can respond both in procyclical and countercyclical patterns with the economy (Macunovich, 1995). Risk factors and associated racial disparities are also situated in historical context. For example, the first measurement occasion of 1992 was a time that witnessed substantial differences between black and white females in the prevalence of nonmarital childbearing and teen pregnancy, yet these differences declined over the study period (Romero, 2016; Sweeney & Raley, 2014). Maternal smoking during pregnancy also became markedly less common during the study period with substantial variation in the decline between states (CDC, 2004). Documenting the effects to birth outcomes of such secular trends and shifts in racial disparities demonstrates potential targets for health initiatives.

Conclusion

Considerable variation in low birth weight incidence exists between counties as well as within counties over time. Differences in LBW incidence between black and white infants are also unique to place and time. Elucidating economic and social predictors of such variation provides insight into potential policy levers that could be employed to improve birth outcomes and attain more equitable health outcomes within counties. The present research makes specific contributions to extant literature by utilizing panel data to estimate inter-temporal within county associations between median income and LBW incidence, models within county fluctuations in black-white disparities in LBW, and tests specific explanations for the link between median income and LBW incidence. The study findings show that increases in median household income are linked with reduced county LBW incidence and decreases in black-white disparities in LBW (also true for very low birth weight outcomes). Increases in county median income appear to be linked with reduced LBW incidence via changes in sociodemographic risk factors among birthing mothers, whereas the estimated benefits to black-white disparities in LBW were unexplained and are an important topic for future research. County governments and other local forms of government therefore can play an important role in identifying local social and economic risks that lead to excess and often inequitable adverse birth outcomes.

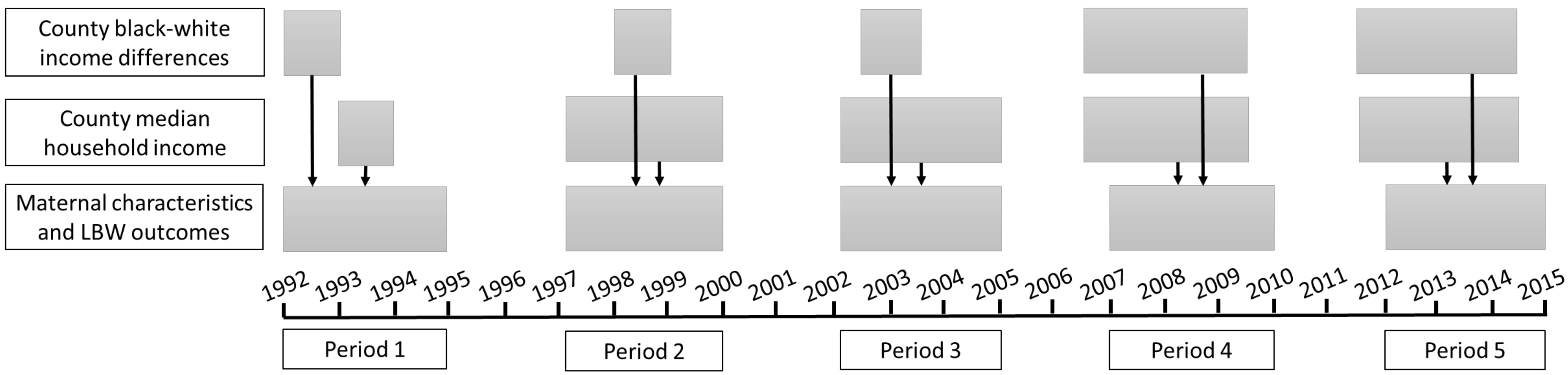

Figure 1. Timeline of measurement occasions for median income estimates, prevalence of maternal sociodemographic and health risks, and low birth weight (LBW) outcomes, with arrows indicating within county hypothesized effects.

Table 1. Descriptive statistics for 732 United States counties, averaged across study periods spanning from 1992 to 2014.

Variables	Black residents M ±SD	White residents M ±SD
Median household income (in $1,000)	36.23 ±13.05	58.12 ±14.29
Maternal sociodemographic characteristics		
% low maternal education (≤ high school diploma)	60.21 ±11.14	42.64 ±12.16
% nonmarital childbearing	70.57 ±11.55	26.53 ±7.36
% teenage pregnancy (< 19 years)	13.19 ±3.59	5.94 ±2.66
% advanced age pregnancy (> 35 years)	8.04 ±3.74	11.87 ±5.78
Maternal health risks		
% maternal smoking during pregnancy	10.59 ±6.01	16.78 ±6.17
% insufficient weight gain (< 15 lbs. gestation adjusted)	16.62 ±4.24	9.77 ±2.49
% inadequate prenatal care (Kotelchuck index)	22.16 ±5.67	10.00 ±3.54
Infant characteristics		
% low birth weight incidence (<2500 grams)	11.61 ±1.60	5.52 ±0.99
% very low birth weight incidence (<1500 grams)	2.49 ±0.43	0.89 ±0.19

Table 2. Bivariate correlations using residualized variables adjusted for county and period fixed effects (*N* = 732 counties and 2798 observations).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1. Population change	-																		
2. Black density	-.11	-																	
3. Median household income	.19	-.33	-																
4. B:W income gap	.09	-.14	.10	-															
5. Low maternal education	-.09	.23	-.22	-.01	-														
6. B:W low maternal education gap	.04	-.04	-.04	.18	.08	-													
7. Nonmarital childbearing	-.23	.33	-.35	-.18	.27	-.03	-												
8. B:W nonmarital childbearing gap	.09	-.10	-.03	.18	.01	.25	-.09	-											
9. Teen pregnancy	-.11	.19	-.08	.08	.10	.02	.12	.10	-										
10. B:W teen pregnancy gap	.01	.03	-.02	.06	-.02	.08	.02	.32	.27	-									
11. Advanced age pregnancy	-.03	.01	.20	.12	-.24	-.02	-.38	.02	.20	.02	-								
12. B:W advanced age pregnancy gap	-.04	.20	.00	-.13	.07	-.18	.05	-.25	.17	-.07	-.13	-							
13. Maternal smoking	.00	-.12	-.11	-.02	-.01	-.07	.23	-.02	-.16	-.01	-.28	-.04	-						
14. B:W maternal smoking gap	-.01	-.14	.05	-.06	-.06	.13	-.05	.19	-.19	-.01	-.02	-.12	-.22	-					
15. Insufficient weight gain	-.05	.12	-.12	-.02	.01	-.02	.11	-.03	.02	.00	-.03	-.01	.04	-.07	-				
16. B:W insufficient weight gain gap	.03	.03	-.01	.07	.01	.10	-.07	.04	.04	-.02	.07	.02	.00	-.05	.46	-			
17. Inadequate prenatal care	-.06	.10	-.05	-.04	-.19	-.03	.11	-.06	.18	.04	.09	.10	.01	-.07	.19	.12	-		
18. B:W inadequate prenatal care gap	.02	.06	.00	.07	-.08	.13	-.10	.10	.14	.07	.12	.04	-.01	-.01	.08	.20	.54	-	
19. Low birth weight	-.12	.28	-.20	-.12	.19	-.07	.35	-.11	.05	-.01	-.17	.05	.16	-.09	.09	-.02	.00	-.06	-
20. B:W low birth weight gap	-.01	-.02	-.08	-.07	.05	.00	.01	.09	-.08	.00	-.09	-.07	.08	.15	.03	-.01	-.05	-.02	.30

Note. B:W refers to absolute differences between black and white residents, mothers, or infants using the same metric as the population level variable. Correlations greater than or equal to .04 are significant at the .05 level.

Table 3. Estimates from fixed effects models testing associations between fluctuations in county median household income on incidence of low birth weight per 100 births (*N* = 732 counties for a total of 2798 observations).

	Model 1a		Model 1b		Model 1c		Model 1d	
	Est.	[95% CI]	Est.	[95% CI]	Est.	[95% CI]	Est.	[95% CI]
Population change (10%)	**-.11**	**[-19, -.04]**	-.06	[-.12, .01]	**-.12**	**[-.19, -.04]**	-.06	[-.13, .02]
Black density (10%)	**.81**	**[.58, 1.03]**	**.61**	**[.42, .81]**	**.92**	**[.70, 1.13]**	**.69**	**[.50, .88]**
Median household income (10k)	**-.27**	**[-.37, -.17]**	-.08	[-.18, .02]	**-.19**	**[-.28, -.09]**	-.05	[-.15, .05]
Maternal sociodemographics								
Low maternal education (10%)			**.12**	**[.02, .21]**			**.12**	**[.02, .21]**
Nonmarital childbearing (10%)			**.50**	**[.38, .62]**			**.44**	**[.32, .56]**
Teenage pregnancy (10%)			-.09	[-.40, .22]			.03	[-.27, .34]
Advanced age pregnancy (10%)			**-.30**	**[-.54, -.06]**			-.19	[-.43, .06]
Maternal health risks								
Smoking during pregnancy (10%)					**.51**	**[.37, .65]**	**.35**	**[.22, .48]**
Insufficient weight gain (10%)					.10	[-.02, .22]	.09	[-.03, .21]
Inadequate prenatal care (10%)					-.07	[-.18, .03]	-.07	[-.17, .04]

Note. Linear estimates (Est.) in bold are significant at p <.05. Period and county fixed effects are included in all models.

Table 4. Estimates from fixed effects models testing associations between fluctuations in county median household income and the racial income gap on black-white differences in low birth weight incidence per 100 births (*N* = 732 counties for a total of 2798 observations).

	Model 2a		Model 2b		Model 2c		Model 2d		Model 2e	
	Est.	[95% CI]	Est.	[95% CI]	Est.	[95% CI]	Est.	[95% CI]	Est.	[95% CI]
Population change (10%)	.01	[-.19, .22]	.03	[-.18, .24]	.00	[-.20, .20]	.04	[-.16, .25]	.02	[-.18, .22]
Black density (10%)	-.44	[-.82, -.06]	**-.51**	**[-.89, -.13]**	-.34	[-.72, .05]	-.32	[-.71, .06]	-.21	[-.60, .19]
Median household income (10k)	**-.56**	**[-.82, -.30]**	**-.54**	**[-.80, -.28]**	**-.47**	**[-.73, -.22]**	**-.54**	**[-.80, -.29]**	**-.50**	**[-.75, -.25]**
Black-white gap (B:W) in income (10k)			**-.26**	**[-.42, -.09]**	**-.32**	**[-.50, -.15]**	**-.21**	**[-.38, -.05]**	-.26	[-.43, -.09]
B:W in maternal sociodemographics										
B:W low maternal education (10%)					-.07	[-.28, .14]			-.11	[-.32, .10]
B:W nonmarital childbearing (10%)					**.39**	**[.18, .61]**			**.30**	**[.08, .52]**
B:W teenage pregnancy (10%)					-.23	[-.67, .21]			-.15	[-.60, .29]
B:W advanced age pregnancy (10%)					**-.49**	**[-.94, -.04]**			-.42	[-.86, .02]
B:W gap in maternal health risks										
B:W smoking during pregnancy (10%)							**.86**	**[.57, 1.15]**	**.77**	**[.47, 1.07]**
B:W insufficient weight gain (10%)							.02	[-.28, .33]	.02	[-.28, .33]
B:W inadequate prenatal care (10%)							-.07	[-.29, .15]	-.07	[-.29, .15]

Note. Linear estimates (Est.) in bold are significant at $p < .05$. Period and county fixed effects are included in all models.

General Discussion

If a historical perspective is taken, the likelihood of infant mortality in developed countries today is stunningly low. Around 6 infants die per 1000 live births in the United States in recent years (Mathews, MacDorman, & Thoma, 2015), a rate that is down from approximately 100 per 1000 births one-hundred years ago in 1918 (Linder & Grove, 1943). Considerable progress has also been made to reduce the absolute disparity in mortality between black and white infants. The most noteworthy period in terms of obtaining greater equity between black and white infants was toward the end of the civil rights movement. Strong evidence exists that desegregating hospitals in the U.S. South and the ensuing improved access to healthcare decreased the mortality rate for black infants from 40 to 24 per 1000 live births from 1965-1975—a rate that was still ~1.7 higher relative to whites (Almond et al., 2006). Since then, the absolute disparity has continued to drop while the relative disparity (i.e., black-white infant mortality ratio) has risen and hovered around 2.2 in recent decades (Loggins & Andrade, 2013). Thus, although progress should be recognized, the substantial disparities in adverse birth outcomes that exist between black and white infants remain a pressing public health concern.

Differences in the incidence of adverse birth outcomes between various geopolitical designations are also large and represent an understudied topic that merits attention. Findings from this dissertation highlight the variation that exists between counties in overall LBW incidence and the black-white LBW gap, but the focus was on understanding the influence of within county inter-temporal links between policy and economic determinants of LBW outcomes. More specifically, the primary aim of the two studies was to examine whether changes in the provision of public goods or the level of resident economic resources influences the incidence of LBW outcomes and the black-white LBW gap. These findings have implications for the development of geographic disparities in birth outcomes between counties.

One key finding from this dissertation pertains to the role of parks and recreation services (PRS) in reducing county LBW incidence. Prior research has shown that access to high-quality, safe parks and to recreational programming helps encourage healthy behaviors among residents, such as physical activity, and to promote social relationships and youth educational attainment (Hunter et al., 2015; Peters, Elands, & Buijs, 2010; Pfeifer & Cornelissen, 2010; Wells & Evans, 2003). We found that expanding PRS also potentially has indirect benefits on maternal and infant health, manifest as reduced incidence of LBW. This is the first study to document benefits for birth outcomes of local government expenditures on PRS, but the findings are consistent with existing literature on the influence of greenness and proximity to parks on maternal and infant health (Banay et al., 2017; Grazuleviciene et al., 2015). Such findings, if confirmed by future research, demonstrate the potential for PRS to serve as a policy lever through which local governments could implement preventive initiatives to improve birth outcomes. Future research should examine mechanisms underlying the link between PRS expenditures and LBW incidence (e.g., maternal sociodemographic characteristics, health risks). Moreover, an important topic to consider is whether PRS could influence a broad variety of other outcomes, such as fostering social relationships, adult morbidity, and cognitive functioning.

Another key finding was that positive fluctuations in median household income were associated with reduced LBW incidence and smaller black-white LBW disparities. These findings demonstrate that median income increases within areas do not disproportionately benefit more historically advantaged individuals, at least in terms of maternal and infant health, rather rising income is associated with greater equity in birth outcomes between black and white infants. That affluent counties and states fare well in terms of having smaller racial or economic health disparities has been identified in multiple studies (Chetty et al., 2016; Cullen et al., 2012; Siddiqi et al., 2016), with the present dissertation being the first to demonstrate this link between county median income and birth outcomes. It is of concern, therefore, that real median income levels have been stagnant for the bottom half of income earners while nearly doubling for the highest decile of income earners (Piketty, Saez, & Zucman, 2016). Counties and other forms of governments should consider the population health benefits and greater health equity that would stem from policies that encourage widely shared household income growth.

Conclusion

Longstanding interest in the health and survival of infants has spurred many clinical, public health, and social advancements. Eliminating disparities between black and white infants has proved difficult, however, as black infants remain between two- and three-times more likely to experience many adverse birth outcomes. Lu et al. (2010) listed 12 recommendations to help close the black-white gap: the first four points concerned improving the quality of healthcare received throughout the life course; the next four focused on family and community systems (e.g., father involvement, community building); and the final four addressed eliminating social and economic inequities (e.g., reduce poverty, undo racism). Our analyses address many of these recommendations. In particular, we have shown evidence that increasing PRS could add needed community resources with the potential to improve birth outcomes among black infants, which may be especially true where existing access is inequitably distributed (Dahmann et al., 2010; Wolch et al., 2005). Surprisingly, results were inconclusive whether declining racial income (and maternal education) differences would influence the black-white gap in birth outcomes, but this is an important topic for future research. Overall median income growth appears to be an important approach for shrinking black-white disparities in birth outcomes.

In conclusion, 2020 national health objectives to reduce infant mortality have been met (although not for low birth weight incidence), but the reduction of black-white disparities in adverse birth outcomes—an overarching goal of Healthy People 2020—has proved more elusive (Healthy People 2020, 2010). Local governments, with the support of state and federal governments, need to take the initiative to invest public resources, enact public policies, and devise preventive health initiatives in a way that disproportionately benefits groups who have been historically underserved and are at elevated health risk. Such a multidimensional approach to health policy would address key social and economic determinants within communities, and, thereby, reduce existing racial and geographic disparities in adverse birth outcomes.

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Appendices

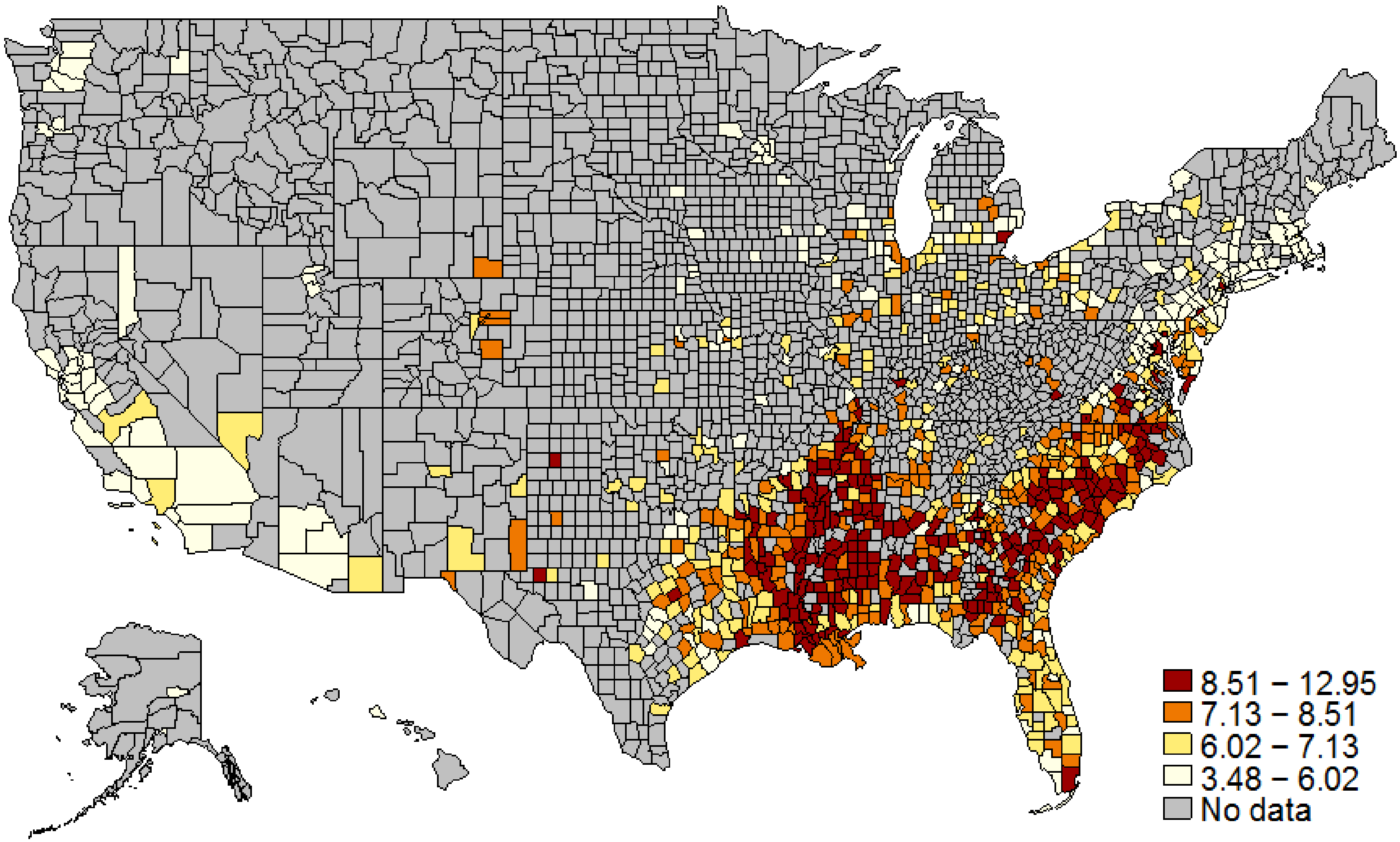

Figure S1. County low birth weight incidence per 100 births among black and white infants for counties included in Study 1 analyses (N=956 counties), averaged across five measurement occasions between 1992 to 2014.

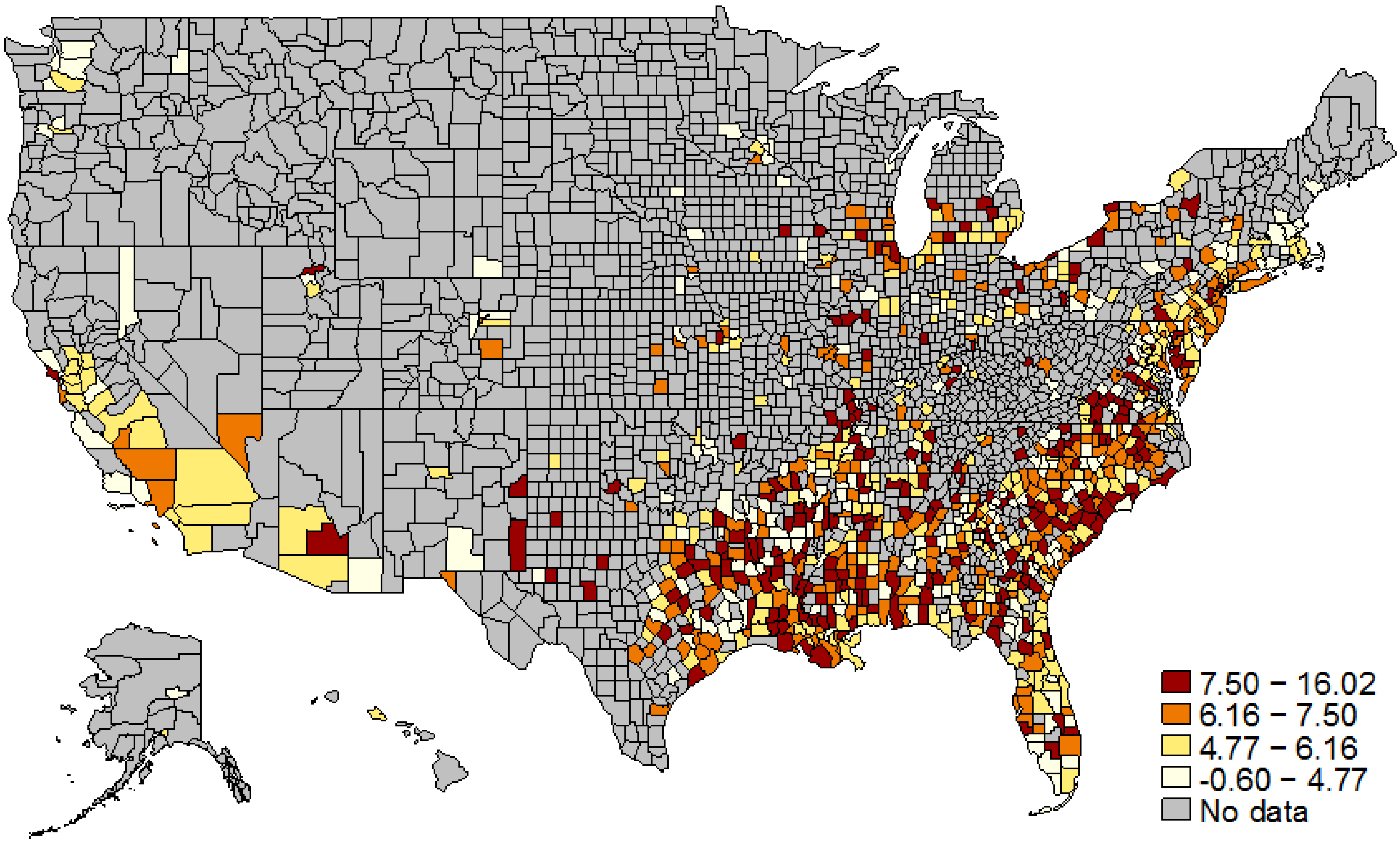

Figure S2. Racial gap in county low birth weight incidence per 100 births between black and white infants for counties included in Study 1 analyses (*N*=956 counties), averaged across five measurement occasions between 1992 to 2014.

Table S1. Estimates from bias corrected fixed effects models indicating the influence of local government expenditures on changes in county incidence of very low birth weight (VLBW) per 1000 live births *(n* = 387 counties; 1427 observations).

	Model 1		Model 2		Model 3	
	Estimate	[95% CI]	Estimate	[95% CI]	Estimate	[95% CI]
$VLBW_{(t-1)}$ (1/1000 live births)	**.44**	**[.27, .60]**	**.44**	**[.27, .61]**	**.22**	**[.09, .36]**
Local government expenditures ($100 per capita)						
Total operational	-.02	[-.05, .01]	-.02	[-.05, .02]	-.02	[-.05, .01]
Housing and community development	.13	[-.23, .48]	.11	[-.30, .53]	.10	[-.26, .46]
Parks and recreation	-.32	[-.82, .18]	-.29	[-.79, .20]	-.31	[-.74, .13]
Health	-.02	[-.21, .16]	-.02	[-.21, .17]	.02	[-.16, .20]
Hospitals	.02	[-.04, .09]	.02	[-.06, .10]	.03	[-.03, .09]
Total $operational_{(t-1)}$			.00	[-.03, .03]	.01	[-.02, .03]
Housing and community $development_{(t-1)}$			.00	[-.34, .34]	.06	[-.30, .43]
Parks and $recreation_{(t-1)}$			.20	[-.34, .74]	.22	[-.32, .76]
$Health_{(t-1)}$			-.04	[-.27, .18]	-.03	[-.23, .16]
$Hospitals_{(t-1)}$			.01	[-.05, .08]	.01	[-.04, .07]
Demographic and economic covariates						
Median household income ($10,000)					-.26	[-.59, .07]
Percent black (10%)					**2.76**	**[1.92, 3.61]**
Population change (10%)					**-.54**	**[-.89, -.19]**

Note. Estimates in bold are significant at $p < .05$. Period fixed effects are included in all models.

Table S2. Estimates from bias corrected fixed effects models indicating the influence of local government expenditures on changes in county black-white differences in incidence of very low birth weight per 1000 live births *(n* = 387 counties; 1427 observations).

	Model 4		Model 5		Model 6	
	Estimate	[95% CI]	Estimate	[95% CI]	Estimate	[95% CI]
Racial gap in VLBW$_{(t\text{-}1)}$ (1/1000 live births)	.05	[-.05, .14]	.05	[-.05, .14]	.05	[-.06, .15]
Local government expenditures ($100 per capita)						
Total operational	-.05	[-.11, .00]	-.05	[-.11, .02]	-.04	[-.11, .04]
Housing and community development	.23	[-.60, 1.06]	.15	[-.71, 1.01]	.18	[-.77, 1.12]
Parks and recreation	.14	[-.96, 1.24]	.18	[-.89, 1.26]	.25	[-.85, 1.36]
Health	.05	[-.42, .52]	.08	[-.38, .55]	.06	[-.41, .53]
Hospitals	**.11**	**[.01, .21]**	.10	[-.01, .21]	.09	[-.05, .22]
Total operational$_{(t\text{-}1)}$			.05	[-.04, .14]	.05	[-.03, .13]
Housing and community development$_{(t\text{-}1)}$			.28	[-.82, 1.37]	.23	[-.91, 1.35]
Parks and recreation$_{(t\text{-}1)}$			.81	[-.67, 2.29]	.80	[-.62, 2.21]
Health$_{(t\text{-}1)}$			-.61	[-1.27, .05]	**-.65**	**[-1.25, -.05]**
Hospitals$_{(t\text{-}1)}$			-.03	[-22, .17]	-.03	[-.21, .15]
Demographic and economic covariates						
Median household income ($10,000)					-.73	[-1.87, .42]
Percent black (10%)					-1.40	[-3.17, .36]
Population change (10%)					.19	[-.80, 1.17]

Note. Estimates in bold are significant at p <.05. Period fixed effects are included in all models.

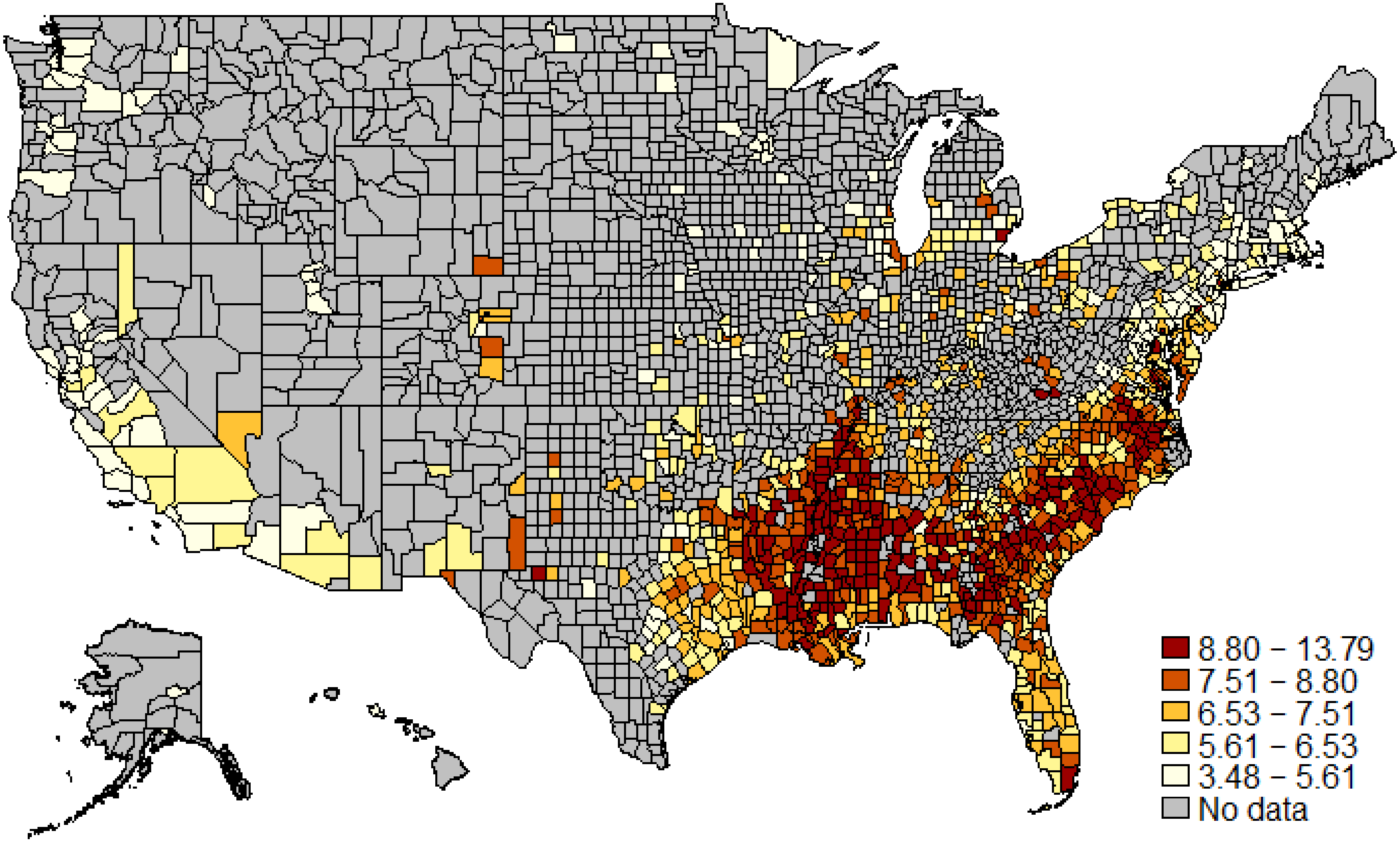

Figure S3. County low birth weight incidence per 100 births among black and white infants, five measurement occasions between 1992 to 2014.

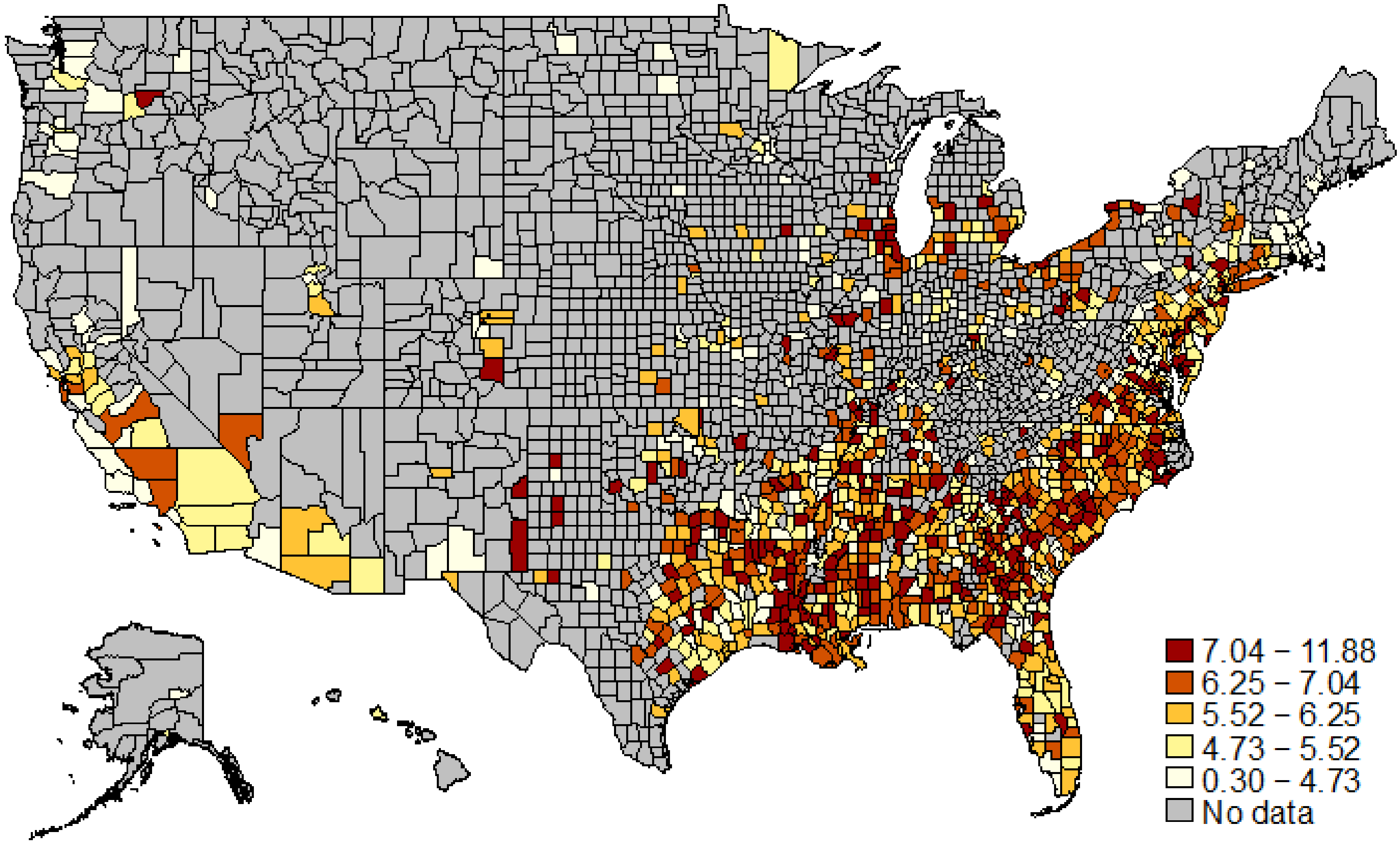

Figure S4. County absolute differences between black and white infants in low birth weight incidence per 100 births, five measurement occasions between 1992 to 2014.

Table S3. Correlations using county mean values across five measurement occasions (*N* = 732 counties).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
1. Population change	-																		
2. Black density	-.33	-																	
3. Median household income	.45	-.49	-																
4. B:W income gap	-.10	.10	.26	-															
5. Low maternal education	-.33	.46	-.80	-.29	-														
6. B:W low maternal education gap	-.13	.08	.06	.61	-.25	-													
7. Nonmarital fertility	-.50	.77	-.77	.00	.74	.09	-												
8. B:W nonmarital fertility gap	-.36	.40	-.35	.52	.19	.57	.45	-											
9. Teen pregnancy	-.39	.63	-.84	-.12	.86	-.09	.84	.39	-										
10. B:W teen pregnancy gap	-.25	.12	-.19	.45	.05	.63	.32	.70	.20	-									
11. Advanced age pregnancy	.24	-.38	.82	.33	-.81	.29	-.60	-.14	-.82	-.07	-								
12. B:W advanced age pregnancy gap	.10	.09	-.34	-.59	.51	-.67	.14	-.41	.40	-.43	-.65	-							
13. Maternal smoking	-.23	-.27	-.42	-.31	.44	-.24	.20	-.02	.33	.10	-.49	.30	-						
14. B:W maternal smoking gap	.05	-.43	.51	.31	-.67	.43	-.47	.07	-.69	.27	.60	-.55	-.22	-					
15. Insufficient weight gain	-.34	.61	-.61	-.07	.62	-.05	.65	.31	.68	.08	-.54	.28	.16	-.49	-				
16. B:W insufficient weight gain gap	-.07	.25	-.13	.28	.11	.37	.20	.37	.15	.23	-.04	-.10	-.11	.03	.50	-			
17. Inadequate prenatal care	-.27	.44	-.52	-.07	.53	-.01	.57	.22	.55	.19	-.41	.10	.14	-.34	.48	.17	-		
18. B:W inadequate prenatal care gap	-.18	.06	-.04	.45	-.04	.52	.16	.48	.07	.55	.08	-.34	.00	.24	.09	.34	.40	-	
19. Low birth weight	-.42	.84	-.74	-.02	.69	.03	.86	.45	.84	.16	-.60	.20	.06	-.54	.68	.22	.50	.07	-
20. B:W low birth weight gap	-.15	.21	-.23	.29	.13	.35	.23	.56	.22	.45	-.11	-.27	-.02	.07	.18	.24	.11	.28	.35

Note. B:W refers to absolute differences between black and white residents, mothers, or infants using the same metric as the population level variable. Correlations greater than or equal to .04 are significant at the .05 level.