Spatial Inequality in Birth Outcomes: Testing Classes of Mechanisms[1]

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ABSTRACT

Low birth weight and preterm birth have lasting implications for healthy child development. Existing work establish neighborhood effects in birth outcomes but are not able to disentangle more proximate pathways by which spatial contexts generate inequality. We use data from a longitudinal survey of women who delivered live singleton births at the Brigham and Women's Hospital in Boston, MA between 2006 and 2010 and were recruited within 10 weeks of gestation (n = 500). The primary contribution of this study is to determine whether spatial variation in birth outcomes persist when variation in prenatal care is low. Secondly, if variation remains, this study will investigate two classes of mechanisms, neighborhood social support and social stressors (i.e. perceptions of safety), to determine the contributions of each pathway. Finally, clinical measures such as blood pressure and biomarkers for angiogenesis are available longitudinally during pregnancy, allowing for causal mediation analysis.

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I. INTRODUCTION

Disadvantageous consequences of poverty are often pronounced early in the life course, one of the earliest and most detrimental of which is low birth weight (defined as less than 2,500 grams) and preterm birth (delivery before the 37th week of pregnancy). Differences in birth outcomes are a key component of stratification because they both reflect and produce unequal life chances (Strully et al., 2010; Cramer 1995). The risk of infant mortality, long viewed as an indicator of the social development of a society, is highly sensitive to low birth weight (Luke et al 1993; Centers for Disease Control and Prevention, 2014). Given survival, both preterm birth and low birth weight are associated with long-term health conditions and disability in children, including a wide range of neurodevelopmental disabilities (Allen, 2002; Aylward, 2005). Comparisons between siblings show that, on average, low birth weight children experience delayed high school graduation and are 74% less likely to complete college even after controlling for changes in family income (Conley and Bennet, 2000). Lower levels of educational attainment correspond to reduced future income and diminished ability to achieve social goods (Dahrendorf 1979; Duncan and Murnane, 2011). Using natural experiments, studies have confirmed that the negative consequences of low birth weight persist even after factoring out unmeasured characteristics such as prior maternal health and health related attitudes that may influence both poverty and birth outcomes (Strully et al., 2010).

Birth outcomes are of interest to sociologists because they are markers of the intergenerational transmission of inequalities; they are both influenced by maternal health (in turn a function of a mother's own birth weight) and have lasting implications for healthy child development. The intergenerational connection is so strong that controlling for maternal health, individual-level measures of maternal deprivation are often not predictive of poor birth outcomes (Conley and Bennett, 2000). Yet even after controlling for maternal health, birth outcomes are sensitive to social context (i.e. not individual maternal attributes but exposure to collective conditions) during pregnancy (Buka et al. 2002; Roberts 1997; O'Campo, Xue, and Wang 1997; Pearl, Braveman, and Abrams 2001; Rauh, Andrews, and Garfinkel 2001; Gorman 1999; Sloggett and Joshi 1994). Social and material contexts have an impact on behaviors such as diet and smoking, access to health care services, and stress levels during pregnancy (Singh and Kogan, 2007). Additionally, the negative consequences of stress are causal, as identified by studies that exploit natural disasters as an exogenous source of stress (Torche, 2011).

It is well established, in other words, that birth outcomes vary substantially as a consequence of the uneven spatial distribution of material and social conditions. However, few studies are adequately equipped to investigate more specific proximate mechanisms (i.e. quality of prenatal care, community support, crime related stress, environmental toxins, among others) due to data limitations. Individual level characteristics are usually recovered using local Vital Statistics microdata or birth records, which contain only coarse measures of prenatal care such as number of doctor's visits, trimester of prenatal care initiation, and whether deliveries occur in a hospital or not (Morenoff 2003, O'Campo et al 1997, Buka et al. 2002, Sastry and Hussey 2003), but mask substantial remaining variation in quality and quantity of care. While large sample sizes are an advantage of studies that use birth records, the current study will use clinical data to parse out the contributions of prenatal care and baseline maternal health from

other contextual variables, and to explore connections with heterogenous clinical etiologies (McElrath et al. 2008). In terms of contextual variables, as Morenoff (2003) notes, most studies use census data to account for neighborhood socioeconomic status and composition. Very few studies use outside surveys to capture community context; the two exceptions are Buka et al. (2002), who consider spatially embedded social support, and Morenoff (2003), who considers neighborhood crime and spatially embedded social support. Yet there are likely large unobserved differences remaining in quality and quantity of prenatal care[2], which are also likely to strongly correlate with place and contribute to birth outcomes, confounding estimates of other proximate pathways.

In the current study, we will investigate whether spatial variation remains after imposing more specific controls for prenatal care through use of clinical data in combination with precise sample inclusion criteria. We use a unique longitudinal prospective survey of roughly n = 500 women who delivered live singleton births at the Brigham and Women's Hospital (BWH) in Boston, MA, received prenatal care at BWH starting in the first trimester of pregnancy, and resided within Suffolk County, MA between 2006 and 2010. These data are one of the nation's largest pregnancy cohorts and specimen banks. We will first determine whether neighborhoods effects on birth outcomes are still present among women who receive quality prenatal care through their pregnancy. Given that we find that spatial inequalities persist, we will also test for two proximate spatial pathways by which spatial context generates inequality in birth outcomes (1) social stressors due to crime and (2) community support, in order to investigate the relative contributions of different proximate pathways connecting neighborhoods with birth outcomes. Finally, our research also makes the point that clinical data are infrequently leveraged in sociological work on birth outcomes and spatial inequalities, yet present unique opportunities to disentangle mechanisms through specific medical data and exact patient addresses. To those ends, we also consider more specific clinical birth outcomes (McElrath et al 2008) and biomarker intermediates throughout analyses, to understand whether different classes of spatial processes could become embodied through different biological pathways.

Establishing that inequalities in birth outcomes exist has only tenuous policy implications, falling under general appreciation for spatial externalities and community-based interventions. However, it is difficult to derive priorities and specific recommendations on methods and sites of intervention without a better understanding of why and how place matters. This study contributes to understanding of which classes of mechanisms are most likely to contribute to inequality in birth outcomes in the first place. This paper's analyses of why place and context matter therefore provide novel implications for strategies of addressing inequalities in health, in terms of what places and people to target, what spillovers to expect, and how (Macintyre, MacIver, and Sooman, 1993; Sooman, Macintyre, and Anderson 1993).

II. PROCESS TURN IN THE HEALTH INEQUALITIES LITERATURE

In the past decade, the broader sociological literature on neighborhoods has moved from establishing that inequalities in outcomes such as crime or educational attainment exist and onto attempting to explain how and why neighborhoods matter

[2] Buka et al. (2002) consider only late (third trimester) or lack of prenatal care. Morenoff (2003) considers numbers of doctor's visits, but neither timing of care nor quality of institution delivering care.

through more proximate mechanisms. This shift is sometimes referred to as the "process turn" (Sampson et al., 2002). However, research on inequalities in health has not experienced as much of a process turn (Morenoff and Lynch, 2004). For instance, scholars understand that neighborhoods matter for child and adolescent development (Brooks-Gunn et al., 1993), starting at birth (Buka et al., 2003; Morenoff, 2003; Rauh et al., 2001). There exist many studies on the association between local area characteristics and birth weight, including city-specific studies of Chicago (Buka et al. 2002; Roberts 1997), Baltimore (O'Campo, Xue, and Wang 1997), Los Angeles (Pearl, Braveman, and Abrams 2001), and New York (Rauh, Andrews, and Garfinkel 2001), one national study of the United States (Gorman 1999), and one national study of the United Kingdom (Sloggett and Joshi 1994). Such studies all report significant associations between at least one measure of local area socioeconomic composition and birth weight, after controlling for socioeconomic status at the individual level. Yet although it is well established that birth outcomes vary by neighborhoods, few studies have investigated the proximate pathways through which neighborhoods matter, in part, because only two studies to this date have used non–census-based neighborhood measures of community context (Buka et al. 2002; O'Campo et al. 1997). In addition, thus far, all sociological studies of neighborhoods effects in birth outcomes use only coarse controls for prenatal care, which is likely to correlate with both neighborhoods and birth outcomes.

There are at least three reasons for why health research on spatial context lags behind the broader sociological literature on neighborhoods effects, and three corresponding motivations for the current study. Firstly, the individual-level paradigm drives most health research, such that contextual factors are not adequately conceptualized or considered (Krieger, 1994; Palloni and Morenoff, 2001; Schwartz, Susser, and Susser, 1999). Secondly, lack of a process turn in health literature may be connected to emphasis on fundamental (distal) over proximate causes of health inequalities (Link and Phelan 1995). Fundamental cause theory presents sharp theory on the persistence of inequality but may have the unintended consequence of leading researchers to prioritize documenting the persistence of socioeconomic inequalities over identifying specific proximate mechanisms. The current project will move past the individual-level paradigm in the case of birth outcomes and consider a broad set of proximate contextual variables, while still accounting for individual-level risk factors as controls.

Thirdly, studies of health inequalities are hindered by data restrictions. Although earlier foundations for urban sociology view communities as natural areas or subsections with internally consistent and derived characters (Park, 1916), later theoretical work reformulates neighborhoods not as discrete units but nested ecological communities within broader groupings (Suttles, 1972), which paved the way for a shift in emphasis on proximate mechanisms in recent neighborhoods studies (Sampson et al. 2002). In other words, the processes by which spatial context becomes embodied may require more fine-grained linkages between individual outcomes and spatial experiences that may not aggregate neatly to wider spatial areas, but instead be crosscutting. This view is supported by evidence that place effects tend to be stronger when using smaller geographic units that reveal a greater extent of systematic spatial patterns otherwise hidden by aggregate analyses (Boyle and Williams, 1999, Morenoff, 2003). Yet research on spatial inequalities in health tend to rely on the internal composition of discrete

neighborhoods derived from census data (Roberts, 1997; Gorman 1999), and this extends to research on spatial inequalities in birth outcomes, among which only two sociological studies to date use non-census-based neighborhood measures of community context (Morenoff 2003; Buka et al 2002). The current study is thus (1) among the first to study proximate pathways towards spatial inequalities in birth outcomes and (2) the first to limit confounding due to receipt of prenatal care.

This project will take advantage of a novel dataset (roughly N = 500) following a cohort of pregnant women who reside in Suffolk County, MA and receive prenatal care at the Brigham and Women's Hospital (BWH) beginning in their first trimester. Alongside the usual demographic variables and birth outcomes contained in vital statistics, this data contains a rich set of individual-level clinical measures at birth, biological markers from prenatal visits, and exact addresses and dates of three visits during pregnancy. The selective sample combined with a rich set of clinical variables allow us to consider firstly, whether proximate pathways identified in prior work are robust to strong controls for the quantity or quality care, or whether they persist among a sample of women that receive similar and consistent care throughout their pregnancy. Since other birth records (i.e. Vital Statistics) come from hospitals but do not make this information available, the contribution of spatial sorting into modes of prenatal care is currently unknown. Our plan is to investigate whether spatial inequalities in birth outcomes could be driven by proximate mechanisms within two broad categories (1) maternal stress from the ecological environment (i.e. perceptions of lack of safety, or public disorder) or (2) community support (i.e. large local networks and high reported trust in neighbors), where exact addresses in clinical data are matched at the tract[3] level BNS (Boston Neighborhood Survey), and other spatial controls are derived from the census.

III. IDENTIFYING HETEROGENEOUS ETIOLOGIES

In addition to engaging the process turn, use of clinical data has several additional benefits. Clinical data allow us to test whether classes of mechanisms correspond with different biological pathways towards poor birth outcomes. Sociologists are often reluctant to produce explanations of social patterns or processes that involve biological indicators in part because of the concern that greater attention to "biology" diminishes the value of social explanations (Freese et al., 2003; Bearman 2008). In other words, many sociologists feel that they must not report that there are genetic effects on behaviors and outcomes or vice versa. However this orientation towards biology removes sociology from the scene of broader public debates (Bearman 2008; Ellis, 1996). The worry that more specific conceptualizations of biology justifies inequalities or diminishes social explanations of inequality is unfounded. Instead, more specific conceptualizations of biology can reveal elements of social structure without reducing outcomes or processes to genetics (Bearman 2008). Biological and clinical data can be used as an effective lever for revealing stratification (Freese et al., 2003). There are some notable exceptions to this aversion. For instance, consider the finding that maternal socioeconomic status is not predictive of birth weight after controlling for maternal birth-weight, but that birth weight

[3] Census tracts are small, relatively permanent county subdivisions intended to provide a stable set of geographic units for the presentation of statistical data. There are 156 census tracts captured by the Boston Neighborhoods Survey and included in the current study.

matters for future socioeconomic status (Conley and Bennet, 2010). This work has not been interpreted to imply that birth outcomes are biologically or genetically determined or that socioeconomic status is genetically determined, but rather indicate that the socially determined intergenerational cycle of poverty and ill health are fully embodied at both the maternal and infant level, and made visible by its association with birth weight.

Biological pathways towards spatial inequality in birth outcomes will be carefully considered in the current study, (A) in considering biological intermediates and (B) in considering various birth outcomes. In terms of birth outcomes, this study takes both precise gestational age at birth and birth weight as outcomes rather than a binary cutoff, which is useful in order to understand the biological pathways towards healthy birth outcomes (Ferguson et al, 2013). In addition, recent developments in epidemiological work indicate that preterm births can be categorized into different etiologies, e.g. inflammatory, placental, and procedural (McElrath et al. 2008), and the etiology of preterm births are available to this analysis. The novel attention to biological pathways in this paper is not driven by any sort of biological determinism, but is used to articulate differences in classes of mechanisms, which may correspond with different biological pathways towards poor birth outcomes. In theory, less healthy fetal development and worse birth outcomes due lack of access to care has different physiological consequences and therefore a different biological footprint than stress due to conflict and disorder. Thus, this study bridges sociological work on neighborhoods effects in birth outcomes with cutting-edge advances in the medical field.

In terms of biological intermediates, it is useful to connect classes of mechanisms that correspond with biological pathways, such as using biomarkers, to birth outcomes. Our data contain clinical measures from prenatal visits that help capture and possibly confirm pathways by which birth outcomes are spatially patterned. For a subset of this data, this includes angiogenic factors from blood tests, which can be considered biomarkers that respond to stress. Our data is unique in that it contains one of largest biobanks that include angiogenic factors among all the studies in the US. In addition, blood pressure and fetal growth characteristics are assessed in each trimester of pregnancy, where sudden onset hypertension or high blood pressure during pregnancy (preeclampsia) is a leading risk factor for poor birth outcomes and infant mortality (Bakker et al, 2011). Differences in pregnancy intermediates are likely to indicate different physiological adaptations affecting fetal growth that should be aligned with different types of spatial disadvantage.

IV. DATA AND METHODS

Data

This paper will use a novel dataset composed of expectant mothers who were enrolled prospectively between 2006 and 2010 at the Brigham and Women's Hospital (BWH) in Boston, MA. All women, aged 18 years and older, who were receiving care at BWH or who were referred to BWH before 10 weeks gestation were approached to be a study participant. The clinical study follows up with participants three times during prenatal visits at three trimesters and birth. It is one of the largest prospective cohort studies of birth outcomes in the nation. The analytic sample (roughly n = 500) is composed of all study participants who delivered a live singleton baby.

Clinical studies offer exact addresses for place of residence during pregnancy, which can be matched at the tract level with the Boston Neighborhoods Survey (BNS). The BNS was a telephone survey based on methodology from Raudenbush and Sampson (1999) with over 4,000 participants in three waves (2006, 2008, and 2010) recruited by random-digit dial. These data are then aggregated at the tract level to create longitudinal data on neighborhoods over time. The current study matches BNS data with the main sample of expectant mothers at the tract level with linear interpolation of key measures of social capital at the block level for BNS years that are not surveyed.

Dependent Variables

Clinical cutoffs for low birth weight and preterm birth are 2,500 grams and 27th week of pregnancy, respectively. However, these exact cutoffs for preterm birth and low birth weight are relatively arbitrary and do not correspond to objective biological pathways towards healthy birth outcomes (Ferguson et al, 2013). Therefore, continuous measures of both birth outcomes are used in the current study. We will also consider an alternative birth outcome, preterm birth categorized by observed etiologies (McElrath et al 2008), which fall under three main categories: those associated with intrauterine inflammation, those associated with aberrations of placentation, and those that are "procedural."

Independent Variables

One proximate pathway by which spatial inequalities in birth outcomes could be generated is through differential exposure to stressors in the social environment. Perceptions on neighborhood safety are derived from the BNS (Boston Neighborhoods Survey) questionnaire using responses to the question "Overall, do you consider your neighborhood safe?" on a Likert scale, where higher scores indicate greater perceived safety. Respondents were also asked to indicate their perception of physical disorder in their surroundings[4], where higher scores indicate less disorder.

Spatial inequalities in birth outcomes could be generated by differences in access to care due to differences in network support systems and neighborhood social capital. Measures of average network support at the tract level are derived from averaging responses to the following BNS (Boston Neighborhoods survey) questions: (1) "not counting people who live with you, how many friends live in your neighborhood?" and (2) "not counting people who live with you, how many relatives live in your neighborhood?" Lack of support should theoretical reduce access to care, especially for mothers who already have young children at home (this can be tested, as a robustness check, by including an interaction between social support measures and the number of young children at home). Measures of neighborhood social capital are determined by averaging the perceived ability of the neighborhood to enforce shared norms or goals[5] with the strength of positive social relationships[6] between people in the neighborhood,

[4] Physical disorder based on mean rating for perceived amount of: (1) litter, broken glass, or trash on sidewalks (2) graffiti on buildings and walls (3) vacant lots or deserted houses or storefronts and (4) gunshots and shootings, where (4) factors into the total only for the 2008 wave of the BNS.

[5] These include perceived ability of neighbors to act (1) in keeping open a local fire station (2) intervening with loitering or (3) disrespectful children, and (4) intervening with crime.

[6] Qualities of positive relationships assessed by BNS questionnaire include: trust, willingness to help, knowing and liking, getting along, sharing values.

both on Likert scales where higher values indicate greater amounts of neighborhood social capital.

Controls

All analyses will be net of a comprehensive set of individual control variables. Individual level controls will include maternal demographic and health background information (age, race, educational background, insurance type, gravidity i.e. the number of prior times a woman has been pregnant, whether the pregnancy was planned, weight, and existing health conditions such as diabetes), as well as maternal behaviors (smoking and drinking during pregnancy). Contextual controls include tract level poverty, and tract level demographic composition, which are pulled from the ACS (American Community Survey) 2009 5-Year Estimates, which are collected and released by the Census Bureau.

Although all mothers delivered at BWH and were recruited in their first trimester within 10 weeks of gestation, which provides far stronger control in quality and quantity of prenatal care there are differences in access to care that prior work, we still control for remaining differences in prenatal care by including a control for late or missing study visits (study visit dates are targeted for the middle of each trimester, but correspond less precisely to this target if mothers miss appointments or experience other scheduling difficulties). We also construct additional measures of hospital accessibility to proxy differences in prenatal care. Using the Google Maps API in R version 3.5.1, we have extracted travel times for different modes of transportation (i.e. walking, driving, public transportation) to capture the costs of commute to hospital.

Intermediaries

Causal mediation analyses will be performed on variables that are collected at up to three study visits occurring close to the middle of each trimester. These include blood pressure in all cases, and in some cases, angiogenic growth factors, or biomarkers that indicate the formation of new blood vessels. For nearly all members of the analytic sample, biological assays were performed. This provides levels of expression of Plasma sFlt-1 (SFLT), which restricts angiogenesis, and placental growth factor (PGLF), which encourages angiogenesis.

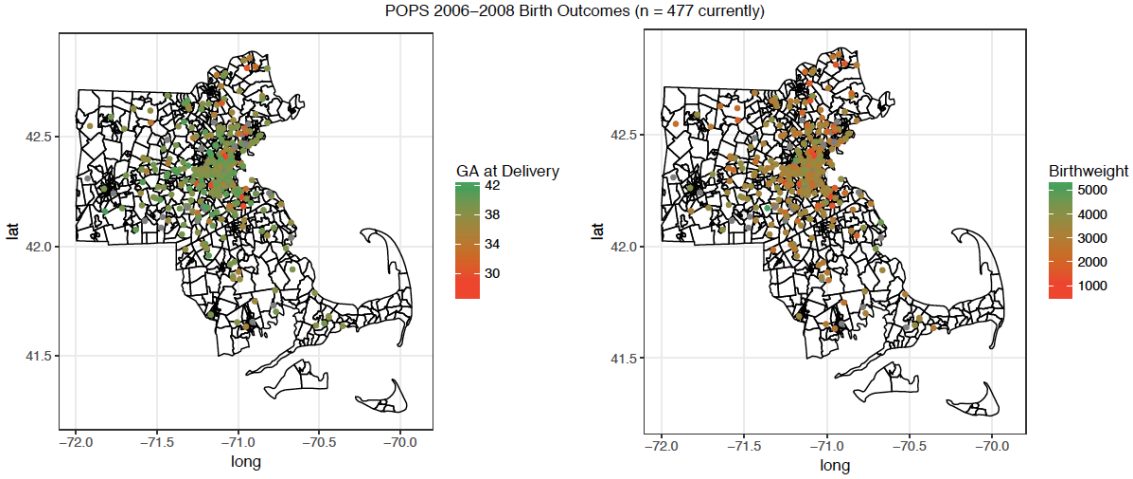
Analytical Strategy

There are 54 zip codes, 18 towns (Boston, Winthrop, Charlestown, East Boston, Mattapan, Roxbury, Revere, Allston, Dorchester, Hyde Park, Readville, Roxbury Crossing, Chelsea, Brighton, Dorchester Center, Jamaica Plain, Roslindale and West Roxbury), and 156 census tracts, that are captured by our data. Our first goal is to determine whether neighborhoods effects exist among our sample. We perform these analyses by using a likelihood ratio test to test whether birth outcomes are better predicted by a simple linear regression that does not account for zip code or a hierarchical model with random effects at the zip code level. Multilevel analyses also allow us to separately estimate the variance in birth outcomes within and between zip codes. We are currently in the process of geocoding addresses and have recovered roughly 2/3 of the n = 500 cases. A summary of birth outcomes by place of residence for this subset of the data is given in Figure 1.

Given that zip codes correspond roughly to neighborhoods, but the pathways that connect neighborhood inequalities to birth outcomes may be more proximate, we next predict birth outcomes using standard multivariate regressions with tract level spatial characteristics as controls. We cluster standard errors at the tract level to account for within-cluster variation but do not need to run multilevel analyses in these case to separately estimate the variance in birth outcomes between and within tracts because the average number of observations per tract is too low for these analyses. Models that include or omit different proximate spatial independent variables can be tested against each other using the likelihood ratio test to determine which are most likely to explain inequalities in birth outcomes. All analyses will control for prior maternal health, rendering results conservative to the overall effects of social and physical environment (since prior maternal health is also a function of environment). Due to availability of not only pregnancy addresses by current addresses for all women, a robustness check can be run on the earlier data in order to determine the extent to which selection into neighborhoods by health status is an issue. Finally, causal mediation analyses will be used to incorporate data on angiogenic growth factors and maternal blood pressure in order to determine whether certain classes of mechanisms follow distinct biological pathways.

V. TABLES AND FIGURES

Figure 1.



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