Metropolitan Residential Segregation and Very Preterm Birth among Black and Hispanic Mothers

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Abstract: Prior research suggests that metropolitan residential segregation is positively associated with poor birth outcomes among black mothers even after adjusting for maternal education, marital status and health behaviors. Place stratification theory posits that this association reflects the high levels of exposure to neighborhood poverty experienced by members of racial-ethnic groups that are both socio-economically disadvantaged and residentially segregated. Hispanics, especially Hispanic immigrants, experience similar levels of socio-economic disadvantage and residential segregation. As such, place stratification theory implies that the relationship between residential segregation and very preterm birth should be similar among black and Hispanic women, particularly when comparing African Americans to Hispanic immigrants. However, little prior research has examined this relationship among Hispanic women, and the few existing studies have produced inconclusive results. In this study, data on 465,271 singleton births to black mothers and 791,855 to Hispanic mothers in over 200 metropolitan areas are analyzed in order to measure the association between one dimension of segregation, residential isolation, and very preterm birth. A multi-level analysis of these data reveals that residential isolation is positively and significantly associated with very preterm birth among both black and Hispanic women, net of a variety of individual and metropolitan-level controls and unobserved heterogeneity between metropolitan areas. While this association is similar among US-born and immigrant black and Hispanic women, it is only robust across different measures of poor birth outcomes (i.e., very preterm birth and very low birthweight) among black, not among Hispanic women.

Introduction

Non-Hispanic black infants born in the United States are more than twice as likely as white children to die during their first year, in large part because they are more likely to be born preterm and more likely to die from associated complications (Mathews & MacDorman, 2008). The vast majority of infant deaths associated with preterm birth involve infants born prior to 32 weeks of gestation, so-called very preterm births. However, disparities between non-Hispanic blacks and whites in very preterm birth are much more pronounced in some metropolitan regions than in others, mostly because rates among black mothers vary dramatically across metropolitan areas (Kramer et al., 2010). One reason is that very preterm birth rates are higher among black (but not among non-Hispanic white) mothers in residentially segregated metropolitan areas, even after adjusting for both individual-level risk factors and metropolitan-level socioeconomic status (e.g., the poverty rate among black households in the MSA where the mother resides).

Place stratification theory suggests that this association reflects the concentration of poverty in the neighborhoods inhabited by members of socio-economically disadvantaged racial-ethnic groups within highly segregated metropolitan areas (Alba & Logan, 1993; Logan, 1978; Massey & Denton, 1993). Yet despite similar poverty levels and increasingly similar levels of residential segregation among Hispanics, very preterm birth rates among Hispanic mothers are not only consistently lower, but vary much less across metropolitan areas than those among black women (Kramer & Hogue, 2008). Moreover, the few existing studies of the relationship between metropolitan residential segregation and poor birth outcomes among Hispanics have produced mixed, inconclusive results (Walton, 2009; Osypuk, Bates & Acevedo-Garcia, 2010).

Prior Research on Residential Segregation and Birth Outcomes Among Black Mothers

The evidence of a positive association between metropolitan residential segregation and poor birth outcomes among black mothers is generally robust across studies that focus on different birth outcomes, such as birthweight (Bell, et al., 2006), low birthweight (Bell, et al., 2006; Ellen, 2000; but see Walton, 2009), very low birthweight (Kramer, et al., 2010), fetal growth restriction (Bell, et al., 2006), preterm birth (Bell, et al., 2006; Osypuk & Acevedo-Garcia, 2008) and very preterm birth (Kramer et al., 2010). Studies have produced similar findings using measures of different dimensions of metropolitan residential segregation such as isolation/exposure (Bell, et al., 2006; Kramer, et al., 2010), evenness (Ellen, 2000), centralization (Ellen, 2000) and hypersegregation (Osypuk & Acevedo-Garcia, 2008). Several studies have also documented positive associations between neighborhood racial composition (i.e., percent black in the immediate and/or surrounding neighborhoods) and poor birth outcomes among black mothers in a single city or region, net of adjustments for maternal age, education, and marital status (Grady, 2006; Grady & McLafferty, 2007; Mason et al., 2009; Nibley & Hellerstedt, 2006). Yet the strongest association appears to be between one dimension of metropolitan residential segregation, black residential isolation, and very preterm birth (Kramer, et. al., 2010). Black residential isolation is the weighted average percent black in the neighborhoods inhabited by the black residents of a given metropolitan area. Prior research suggests, then, that very preterm birth rates among black mothers are particularly sensitive to differences between metropolitan areas in the extent to which black residents tend to live in predominantly black neighborhoods.

Residential Segregation, Place Stratification, and Poor Birth Outcomes

Sociologists, epidemiologists and public health researchers have interpreted the documented relationship between residential segregation and poor birth outcomes among black women through the lens of place stratification theory. According to this theory, a combination of institutionalized and decentralized racism generates and perpetuates racial residential segregation, which, in turn, concentrates poverty in the neighborhoods inhabited by socio-economically disadvantaged racial groups (Charles, 2003; Massey & Denton, 1993). For example, because poverty rates are substantially higher among black than among non-Hispanic white households, black–white segregation ensures that, on average, black households will be exposed to higher levels of neighborhood poverty than comparable white households.

Among the most economically disadvantaged members of segregated racial-ethnic groups, within-group residential segregation by class further increases exposure to high concentrations of neighborhood poverty (Massey & Denton, 1993). But the consequences of racial-ethnic residential segregation need not be limited to the poor households in disadvantaged groups. Among black households, for example, perceived racism, discrimination in housing and mortgage lending markets and white flight restrict neighborhood choice even among middle class black households (Charles, 2003). Consequently, middle class blacks typically live in neighborhoods with higher poverty rates, lower median incomes, fewer college graduates, and fewer white neighbors that provide lower returns on investments in homeownership, compared to the neighborhoods inhabited by non-Hispanic whites with the same household incomes (Adelman, 2004; Alba, Logan & Stults, 2000; Flippen, 2004; Logan, 2011).

In turn, disadvantaged neighborhoods provide limited access to a variety of public and private services (e.g., full-service grocery stores and high-quality schools and healthcare facilities) and increase exposure to harmful environmental influences that adversely affect health

outcomes, such as crime, substandard housing, and pollution (Acevedo-Garcia & Osypuk, 2008; Acevedo-Garcia, Osypuk, & McCardle, 2010; Messer, et al., 2006; Miranda, Maxson, & Edwards, 2009; Morenoff, 2003; Morland, Wing, Poole, & Diex Roux, 2002; Peterson & Krivo, 2000). Thus, residential segregation may contribute to disproportionate exposure among black women to acute and chronic stress, poor air and water quality, and toxins such as heavy metals and pesticides, each of which appears to be linked to an increased risk of adverse birth outcomes through specific biological (i.e., neuroendocrine, cardiovascular and/or immunological) mechanisms (Kramer & Hogue, 2009; Miranda, Maxson, & Edwards, 2009). Similarly, black women who live in highly segregated metropolitan areas may be more likely to engage in risky health behaviors such as smoking during pregnancy and less likely to receive adequate nutrition and healthcare (Bell et al, 2007; Kirby & Kaneda, 2005; Moreland, Wing & Diex Rouz, 2002; Perloff & Jaffe, 1999).

Place stratification theory thus offers a plausible explanation for the documented association between metropolitan residential segregation and poor birth outcomes among black mothers. However, place stratification theory is more difficult to reconcile with the comparatively limited evidence on how metropolitan residential segregation is related to poor birth outcomes among Hispanic women. The poverty rates among both blacks and Hispanics are nearly three times higher than the rate of approximately eight percent among non-Hispanic whites (Orrenius & Zavody, 2011). To be sure, Hispanic residents of US metropolitan areas are somewhat less segregated on average (especially from non-Hispanic whites) than black residents, meaning that similar overall poverty rates need not necessarily translate to similar levels of exposure to neighborhood poverty (Charles, 2003; Stults & Logan, 2011). However, Hispanics are more much more segregated from non-Hispanic whites than Asians are, and they are nearly

as residentially isolated and, in some cases, more isolated than blacks in many large metropolitan areas in the Southwest where Hispanics make up a large proportion of the overall population (Charles, 2003; Logan, Stults, & Farley, 2004). Moreover, Hispanic segregation increased in the majority of U.S. metropolitan areas over the past three decades, particularly in metros with relatively small, but growing Hispanic populations, while black-white segregation declined in virtually all metro areas during the same period (Logan, Stults, & Farley, 2004; Stults and Logan 2011).

Partly as a consequence, black and Hispanic households increasingly experience relatively similar levels of neighborhood poverty. Only 5.9 percent of poor non-Hispanic white households residing in US metropolitan areas during the year 2000 lived in census tracts with poverty rates of 40 percent or more (Jargowsky, 2003). Conversely, over twice as many Hispanic households (13.8 percent) and three times as many black households (18.6 percent) lived in high poverty neighborhoods. As these figures suggest, blacks are typically exposed to somewhat higher levels of neighborhood poverty than Hispanics, but both groups are exposed to much higher levels than non-Hispanic whites. Moreover, differences in exposure to neighborhood poverty between African Americans and the roughly two-thirds of Hispanics who are foreign born are even smaller, both since poverty rates are higher among immigrant Hispanics than among either blacks or US-born Hispanics (Orrenius and Zavodny, 2011) and because immigrant Hispanics are more residentially isolated than their US-born counterparts (Alba, Logan & Stults, 2000). Accordingly, place stratification theory implies that metropolitan residential segregation should have effects on birth outcomes among Hispanic and particularly among immigrant Hispanic mothers that are similar to those documented for black mothers.

In fact, however, prior research provides limited evidence of any substantial association between Hispanic residential isolation and poor birth outcomes, particularly among immigrant Hispanic mothers. Walton (2009) finds no evidence of a substantial or statistically significant association between metropolitan Hispanic residential isolation and low birthweight, net of individual and metropolitan level controls and unobserved heterogeneity across metropolitan areas. Conversely, Osypuk, Bates, and Acevedo-Garcia (2010) find a small, but statistically significant negative association between metropolitan exposure to Mexican ethnic enclaves and birthweight among women of Mexican ancestry net of individual and metropolitan-level controls and unobserved heterogeneity, but only among those born in the United States, not among Mexican immigrant women.

Migration Flows, Spatial Assimilation and Residential Isolation

One reason that residential isolation might not be associated with adverse birth outcomes in the same manner for blacks and Hispanics is that the mechanisms that generate and perpetuate residential segregation differ substantially for each of these racial-ethnic groups. To be sure, some evidence does suggest, consistent with place stratification theory, that racial discrimination in housing markets and "white flight" contribute to both black and Hispanic residential isolation (Crowder, Hall and Tolnay, 2011; Pais, South & Crowder, 2009; Turner, Ross, Galster, & Yinger 2002). However, migration flows play a much larger role in determining the level of residential exposure to same race neighbors typically experienced by Hispanic compared to African American residents of US metropolitan areas. The rising levels of Hispanic residential segregation from non-Hispanic whites in the majority of U.S. metropolitan areas during the 1980s and 1990s were strongly associated with the growth in the overall size of the Hispanic

populations of those areas, which resulted in no small part from immigration from Latin America (Logan, Stults, & Farley, 2004). Perhaps more fundamentally, the isolation dimension of segregation is sensitive to changes in relative group size. Consequently, larger Hispanic populations at the metropolitan level necessarily translate into in higher levels of Hispanic residential isolation, even in cases where the Hispanic population is relatively evenly distributed across neighborhoods in relation to other racial-ethnic groups.

Conversely, the relative size of metropolitan black populations has declined only slightly on average as a result of growth in other minority populations and has been little affected by either domestic or international migration on the part of blacks themselves (Frey, 2011; Logan, Stults, & Frey, 2004; Logan & Stults, 2011; Spilimbergo & Ubeda, 2004). Accordingly, the main channel through which migration has influenced black residential isolation is to reduce it by increasing exposure to non-black racial-ethnic minorities, especially Hispanics. Importantly, the resulting decrease in the average level of residential isolation experienced by black residents of U.S. metropolitan areas has not been associated with substantial changes in blacks' residential exposure to non-Hispanic whites (Logan, Stults & Frey, 2004; Logan & Stults, 2011).

Further, the high proportion of foreign born individuals in most metropolitan Hispanic populations contributes to more or less voluntary segregation that may be relatively independent of racism and discrimination. Spatial assimilation theory emphasizes that chain migration is an important factor contributing to ethnic residential segregation (Massey, 1985). After the initial arrival of the first migrants belonging to a specific racial-ethnic group, immigrant settlement patterns increasingly reflect the social ties between more established and more recent immigrants, with the former playing a key role in finding housing and employment for newer arrivals. The result is to concentrate immigrant settlement in enclaves that develop in and around

the immediate vicinity of the neighborhoods where the earliest migrants established themselves. As enclaves become larger, this process is reinforced by the development of ethnic institutions, such as native language newspapers, churches, social clubs, and ethnically targeted businesses and social service agencies. Such institutions, in turn, foster ethnic solidarity and encourage additional immigrants to settle in enclave neighborhoods. Thus, ethnic residential segregation reflects the key role played by enclave neighborhoods in facilitating immigrant adaptation to the host society.

As the foregoing implies, spatial assimilation theory predicts that residential isolation will decrease among members of specific racial-ethnic groups as they spend more time in the host country and even more so across generations, as the resources provided by enclaves to support adaptation to the host country become less relevant (Massey, 1985). Such spatial assimilation should be particularly pronounced among those members of a given racial-ethnic group who become fluent in the dominant language of the host country and achieve upward socio-economic mobility over time and across generations. Language skills, interethnic social ties, human capital, and financial resources all serve to further reduce the importance of the ethnic resources offered by enclave neighborhoods for finding employment and housing and adapting to the host society more generally. Moreover, these resources facilitate access to desirable residential areas and reduce social distance, thereby facilitating stable residential integration.

Prior research suggests that the process described by spatial assimilation theory plays a larger role in generating and sustaining residential isolation among Hispanics than among blacks. Particularly to the extent that they have become fluent in English, US-born Hispanics and Hispanic immigrants who have spent more time in the United States typically have a higher proportion of Anglo neighbors than recent Hispanic immigrants, meaning that they experience

lower levels of Hispanic residential isolation (Alba, Logan, & Stults, 2000). Conversely, recent black immigrants are typically, if anything, less residentially isolated than African Americans. The distinction between forced and voluntary residential segregation has implications for the relationship between metropolitan residential isolation and birth outcomes among Hispanic mothers. To that extent that Hispanic residential isolation reflects the influence of chain migration and ethnic resources in enclave neighborhoods, it may be associated with greater social support, health enhancing norms (e.g., social pressure to avoid smoking, especially during pregnancy) and other protective factors that reduce the risk of very preterm birth (e.g., see Kimbro, 2009).

Residential Isolation as Institutionalized Racism and Downward Assimilation

Given the relatively prominent role of institutionalized racism and discrimination in generating and sustaining black-white residential segregation, black residential isolation may be positively associated with adverse birth outcomes somewhat independent of the extent to which residential segregation increases exposure to neighborhood poverty among black women. Perceived racism and exposure to discrimination, both during pregnancy and over the life course, are associated with lower birthweight and increased risk of low birthweight, very low birthweight, and preterm birth (Collins, David, & Handler, 2000; Collins, et al., 2004; Mustillo, et al., 2004). Thus, to the extent that black residential isolation is an indicator of the pervasiveness of institutionalized racism, interpersonal racism, or both in the metropolitan areas where black mothers reside, it may be positively associated with very preterm birth even when it does not result in heightened exposure to neighborhood disadvantage. Consistent with this speculation, Grady (2006) found that controlling for neighborhood poverty did not substantially alter the positive association

between black residential isolation and the odds of low birthweight among women who gave birth in New York City. Institutionalized racism, manifested as black residential isolation, may be linked to poor birth outcomes through a number of different pathways, potentially including increased exposure to chronic stress and reduced access to healthcare (Dominguez, et al., 2008; Greene, Blustein, & Weitzman, 2006).

Among Hispanics, nativity may condition the extent to which residential isolation reflects the influence of racism, discrimination and structural inequality. While immigrant enclaves offer resources that facilitate adaptation to the host country among immigrant Hispanics, residential isolation may be indicative of barriers to social and spatial mobility among US-born Hispanics. As such, the relationship between residential isolation and adverse birth outcomes might be more similar to that observed for blacks among US-born Hispanics than among Hispanic immigrants. In particular, US-born Hispanics who experience higher levels of residential isolation may have fallen victim to downward assimilation, i.e., integration into the most disadvantaged segments of society (Zhou, 1997). Among these US-born Hispanics, Hispanic residential isolation may reflect residence in predominantly Hispanic neighborhoods that include substantial proportions of impoverished co-ethnic immigrants. Consistent with this speculation, Johnson & Marchi (2009) find that English-speaking women of Mexican ancestry experience more adverse birth outcomes when they reside in neighborhoods with high proportions of Hispanic immigrants than when they live in areas with fewer immigrants. Conversely, the odds of low birthweight births did not increase significantly in neighborhoods with a high proportion of Hispanic immigrants among Spanish-speaking women from Mexico.

Study Purpose and Objectives

The present study aims to test the implications of place stratification and assimilation theories for poor birth outcomes among black and Hispanic women, focusing on the relationship between residential isolation and the adverse birth outcome mostly closely linked to infant mortality, i.e., very preterm birth. Place stratification theory suggests that residential isolation should be positively associated with very preterm birth among both black and Hispanic mothers, particularly among those who are African Americans or Hispanic immigrants. Moreover, place stratification theory's emphasis on concentration effects suggests that these associations should be partially accounted for by exposure to neighborhood poverty. Alternatively, place stratification's theory emphasis on the role of racism in generating and sustaining residential segregation suggests that residential isolation should be positively associated with the odds of very preterm birth even net of its association with exposure to neighborhood poverty, given that perceived racism and poor birth outcomes are positively associated among black women. Conversely, assimilation theory predicts that Hispanic residential isolation will increase the odds of very preterm birth to a greater extent among US-born Hispanics mothers than among Hispanic immigrant women.

Methods

Data Sources and Measures

Our analysis draws on two sources of data. First, we obtained data on very preterm birth and mothers' characteristics from the U.S. 2004 National Center for Health Statistics (hereafter, NCHS) Birth Data file, which constitutes a census of all U.S. births during this year. To ensure comparability with prior research, our analysis focuses on singleton births to black and Hispanic women who reside in metropolitan areas with at least 100,000 total residents and 5,000 black or

Hispanic residents. Also consistent with prior research, we omitted cases in which the birthweight recorded on the birth certificate took on implausibly extreme values (less than 500 grams or more than 6000 grams). Second, we obtained data on the structural characteristics of metropolitan regions, including the data used to derive measures of metropolitan residential segregation, from the 2000 Census 5 percent sample data (Summary File 3). After imposing the restrictions noted above, we were left with data on 465,271 births to black women in 224 metropolitan areas and 791,855 births to Hispanic women in 207 metropolitan areas.

Birth Outcomes: Our main dependent variable is a dichotomous indicator of very preterm birth, which is set equal to one for all births that took place prior to 32 weeks of gestation. Estimates of gestational age were obtained from information recorded on the infant's birth certificate. In the vast majority of cases (over 93% of both births to both black and Hispanic mothers), gestational age estimates are based on the mother's self-reported date of last normal menstruation. In the remaining cases, the underlying measure of gestational age is based on a clinician's estimate. Both types of estimates are vulnerable to measurement error. Most importantly, maternal recall may be imperfect, particularly in cases where the pregnancy was not planned and/or the mother did not receive or entered late into prenatal care. Accordingly, we also employ an alternative measure of poor birth outcomes, very low birthweight. This dichotomous variable is set equal to one for infants weighing less than 1,500 grams at birth and zero otherwise. Because birthweight is directly measured immediately after birth, its measurement is generally much more reliable than estimates of gestational age. Moreover, approximately 80% of very low birthweight births involve infants born very preterm, and virtually all were born preterm (i.e., prior to 37 weeks of gestation).

Residential segregation: Our analysis focuses on one dimension of residential segregation: residential isolation, measured at the metropolitan level. As noted above, residential isolation measures the mean percent black (Hispanic) in neighborhoods within the focal metropolitan region, weighted by the proportion of the region's total black (Hispanic) population in each neighborhood. As in most research on residential segregation, we use census tracts as proxies for neighborhoods.

Poverty exposure: Following Massey and colleagues (Massey & Fischer, 2000), we also use the exposure index to measure neighborhood poverty. Specifically, the neighborhood poverty exposure index gives the average percentage of poor residents in neighborhoods inhabited by black (Hispanic) residents, weighted by the proportion of the region's total black (Hispanic) population in each census tract.

Additional Independent Measures: We also include several metropolitan-level controls in our models, including the natural log of population size, median household income, and educational attainment (percent with 12 years of education, percent with 13 to 15 years of education, and percent with 16 or more years of education). We also control for the relative size and poverty rate of the focal racial-ethnic group (i.e., blacks or Hispanics). To capture relative size, we include the percentage of each metropolitan area's population that belongs to the focal group. Relative group size is positively associated with the level of segregation experienced by a given group in a specific metropolitan area, i.e., larger black and Latino populations are more segregated (Cutler, Glaeser & Vigdor, 1999; Logan & Stults, 2011). Accordingly, this control is necessary to ensure that the estimated coefficient for residential isolation captures the effects of residential segregation rather than the effects of other characteristics of metropolitan black and

Hispanic populations that are associated with relative size (e.g., influence on central city election outcomes). We also control for the black (or Hispanic) poverty rate in the metropolitan area.

At the individual level, we control for maternal age (using a series of dummy variables to capture its non-linear relationship with the risk of very preterm birth); nativity (i.e., whether foreign-born); maternal education (dummies for 12 years, 13-15 years, and 16 or more years, reference = less than 12 years); whether the mother was married; number of prior births; prior pre-term delivery; smoking and alcohol consumption during pregnancy; chronic hypertension; hypertension during the pregnancy; and eclampsia. We do not control for whether the mother had diabetes, since most states did not report gestational and pre-pregnancy diabetes separately, and preliminary analysis revealed that only pre-pregnancy diabetes was associated with very preterm birth in the seven states that did report this information. In addition, we include a control for the sex of the infant. As in most research using the NCHS birth files, we include dummy variables to indicate missing data on smoking and alcohol consumption, since these data are not collected by all states and localities.

We also include controls for the Kotelchuck Adequacy of Prenatal Care Utilization (hereafter APNCU) index (Kotelchuck, 1994). Most prior studies of the relationship between residential segregation and prenatal care adequacy have included measures of prenatal care adequacy. However, they have typically used dummy variables to indicate the trimester of PNC initiation or the Kessner index. Both of these measures have important limitations. Most fundamentally, the Kessner index overstates the proportion of women who receive adequate prenatal care as defined in terms of the timing of the initiation of care and the number of prenatal care visits compared to the recommendations of the American College of Obstetricians and Gynecologists (ACOG). The Kotelchuck index surmounts these limitations, in part by adjusting

the number of visits considered adequate for the length of gestation. Crucially, it also adds an additional category to those used in the Kessner index (adequate, intermediate and inadequate), adequate plus. Adequate plus denotes women who initiated prenatal care by the fourth month of the pregnancy and had 110% or more of the ACOG recommended number of visits, given the length of pregnancy and the timing of the initiation of care. This category includes women for whom major risk factors are identified early in the pregnancy, resulting in their being encouraged to make more than the normally recommended number of visits. Neither the trimester of PNC initiation nor the Kessner index approaches account for this group of high risk women. We note, however, that the Kotelchuck index also has important limitations. It provides no information about the specific content or quality of care and should not be interpreted as such.

Analysis

We apply a random-effect logistic regression model to analyze the effects of metropolitan- and individual-level characteristics on very preterm birth. We assume that interrelated metropolitan characteristics jointly influence a mother's very-preterm-birth risk and adjust standard errors to reflect correlated error terms within groups, since unobserved common group characteristics are transferred to the error term. The error variance is not constant since it depends on the error term at the group level as well as on the fixed covariates. In a random effects model, it is assumed that there is heterogeneity across the metropolitan areas and that this heterogeneity can be modeled by a probability distribution, which means that the intercept varies from one metropolitan area to another. Our random-effect logistic regression model is:

$Y_{ij}|\pi_{ij}$ ~ Binomial $(1,\pi_{ij})$ $\qquad\qquad$ $\pi_{ij} = P(y_{ij} = 1|x_{ij}, z_j, u_j)$

$$logit\{\pi_{ij}\} = \beta_0 + \beta_1 x_{ij} + \beta_2 z_j + u_j + \varepsilon_{ij}$$

$$u_j \sim N(0, \sigma_u^2), \qquad \varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2)$$

where β_0 is a constant, and β_1 and β_2 are vectors of coefficients, corresponding to fixed covariates at the individual level (x_{ij}) and at the metropolitan level (z_j). ε_{ij}, an individual error term, is associated with the *i*th mother in the *j*th metropolitan area and assumed to have a normal distribution with mean 0 and the variance σ_ε^2. A metropolitan-level random component u_j, assumed to be normally distributed with the expected value 0 and the variance σ_μ^2, is included to account for the multilevel structure of the data. This random term u_j applies to all observations in a particular metropolitan area, capturing unobserved effects of metropolitan area characteristics and accounting for the correlation between individuals nested within the same metropolitan area. Inclusion of these errors allows for the possibility that the values of the dependent variables for individual mothers who resided within the same metropolitan area may be correlated (Diez-Roux 2000).

The variance of the level-2 (metropolitan) residual σ_u^2 can be used to estimate the extent to which residual variation in the probability of very preterm birth is influenced by unobserved metropolitan effects. Here, the intra-class correlation coefficient is a useful statistic for quantifying the relative magnitude of within and between metropolitan variance components. The intra-class correlation coefficient measures the proportion of the total outcome variation that involves variation between metropolitan areas. The intraclass correlation is

$$\rho = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_\varepsilon^2}$$

which is the proportion of the total variance contributed by the metropolitan level variance component.

We estimated four specifications of this basic model for each group. Specifically, we first estimated baseline models that included only the measures of residential isolation, the metropolitan-level control variables indicated above (log population size, percent black [Hispanic] in the metro, black [Hispanic] poverty rate, overall median household income, percent of metro area residents over the age of 24 with 12, 13-15 and 16 or more years of education), and the sex of the infant (i.e., the baseline models omitted all individual-level maternal covariates). These models provide an estimate of the total effect of metropolitan residential isolation before accounting for metropolitan-level (i.e., neighborhood poverty exposure) and individual-level, compositional factors that may mediate its effects. We then estimated two models that add controls for different sets of potential mediators. The first controls for the neighborhood poverty exposure index, while the second controls for individual-level maternal characteristics including maternal age, education and marital status; maternal health behaviors and maternal health conditions. Finally, we estimated models with a cross-level interaction term that allowed the effect of residential isolation to vary by the mother's nativity (foreign vs. US-born).

Results

Figure 1 shows the distribution of very preterm birth rates across metropolitan areas for black and Hispanic mothers.[1] The mean rate is roughly 2.2 times higher among black mothers, and the variance across metropolitan areas is also substantially more pronounced. The larger variance of rates among black mothers suggests that birth outcomes may be more sensitive to the specific metropolitan context, potentially including the level of residential isolation, where the mother resided among black compared to Hispanic mothers. Consistent with this speculation, Figures 2 and 3 show that the bivariate association between residential isolation and very preterm birth is

stronger among black than among Hispanic mothers. Figure 3 shows the relationship separately for Hispanic mothers in metropolitan areas that were less than vs. at least 20% Hispanic, since preliminary analysis revealed that there was no significant association without this control. Even with this crude control for the relative size of the Hispanic population, the correlation is well under half as strong ($r = .11$ for metro areas that are less than 20% Hispanics and $r = .17$ in metro areas with larger proportions of Hispanics) as that observed for black mothers ($r = .37$).

We first estimated a baseline model for black mothers which included only the measure of black residential isolation, metropolitan-level controls and infant sex as predictors. The results for the baseline random-intercept model are shown as Model 1 in Table 1. Among the metropolitan-level measures, only residential isolation and the natural log of the metro area's population were significantly associated with very preterm birth among black mothers. Specifically, the model suggests that each standard deviation increase in residential isolation (about 17 percentage points) corresponds to an increase of nearly 13 percent in the odds of preterm birth ($[e^{.007*17}-1]*100 \approx 12.64$).

Model 2 add the neighborhood poverty exposure index. Contrary to place stratification theory's emphasis on the role of neighborhood disadvantage as a mediating factor between residential segregation and poor birth outcomes, the neighborhood poverty exposure index is not significantly associated with the risk of very preterm birth. Moreover, adding this control does not substantially change the estimated effect of black residential isolation. Indeed, a Wald test revealed that the including the neighborhood poverty exposure index does not significantly improve the fit between the model and the data (Wald $\chi^2 = .70$, $p = .40$). Accordingly, we omit the neighborhood poverty exposure index from subsequent models (though we confirmed that

including this measure did not result in any substantive change to the results presented for models 3 and 4, discussed below).

Model 3 adjusts the coefficient for black residential isolation for individual-level maternal characteristics that are associated with the risk of preterm birth. The results for these individual-level control variables are as expected. The relationship between maternal age and the risk of very preterm birth is u-shaped, such that the highest risks are observed among very young mothers (i.e., those under the age of 15) but the risk also increases steadily beginning at about the age of 30. Mothers who are foreign born, those who are married and those who completed more years of education face lower risks of very preterm birth, while those who smoke cigarettes or drink alcohol during pregnancy face higher risks. Cardiovascular problems (hypertension and eclampsia) are also associated with higher risks of very preterm birth, as is inadequate prenatal care. Adjusting for these individual-level risk factors reduces the estimated logit coefficient for black residential isolation by slightly more than 40%. By comparing various model specifications with subsets of these individual-level covariates (not shown), we determined that about two thirds of this decrease results from controlling for prenatal care utilization. Indeed, the dummy variables representing different categories on the APNCU index have particularly large effects. Compared to otherwise similar black mothers who had the ACOG recommended number of prenatal care visits, the odds of very preterm birth are nearly three times higher among those who received inadequate care, i.e., began prenatal late (or not at all) or had fewer than the recommended number of prenatal care visits ($e^{1.077} \approx 2.93$). Even more strikingly, however, the odds of very preterm birth are over five times higher among black mothers in the adequate plus category, who had more than the ACOG recommended number of visits, compared to those who received adequate care ($e^{1.712} \approx 5.54$).

Finally, model 4 adds a cross-level interaction term which allows the effect of residential isolation to vary by the mother's nativity (i.e., according to whether she was born in the United States). While we did not expect to find large differences between foreign and US-born black mothers, we present the results from this model in order to provide a basis for comparison with the same model specification estimated for Hispanic mothers (and discussed below). While the interaction term is positive (suggesting that black residential isolation is associated with increased risk of very preterm birth to a greater extent among immigrant than among US-born black mothers), it is not statistically significantly different from zero. Accordingly, the interaction model does not significantly improve the fit between the model and the data (Wald $\chi^2 = 2.23$, $p = .14$), and we cannot reject the null hypothesis that residential isolation is associated with very preterm birth in the same manner among immigrant and US-born black mothers.

Table 2 presents the corresponding results for Hispanic mothers. Hispanic residential isolation is positively and significantly associated with very preterm birth among Hispanic mothers. The baseline model (model 1) suggests that the predicted odds of very preterm birth increase by about 22% for each one standard deviation increase in the level of Hispanic residential isolation (about 20 points). While the percentage increase in the predicted odds associated with higher levels of residential integration is substantially greater than for black mothers, the corresponding baseline probability is much lower, meaning that this larger percentage increase in the odds will typically translate to smaller increases in the predicted probability. In contrast to the baseline for black mothers, the baseline model for Hispanic mothers suggests that several metropolitan-area characteristics, along with infant sex, are significantly associated with the risk of very preterm birth. In addition to the significant positive association between (the natural log of) population size and very preterm birth, the model

identifies the education level of metropolitan area residents as a moderately important predictor variable. Further, the odds of very preterm birth are over 15 percent lower among Hispanic female infants than among Hispanic male infants ($100*[e^{-.166} - 1] \approx -15.3$).

Model 2 adds the neighborhood poverty exposure index as a control in order to assess whether poverty exposure mediates the effect of residential isolation. This measure is not significantly associated with the risk of very preterm birth, net of the model. Moreover, the coefficient for residential isolation remains virtually unchanged. As was the case for black mothers, adding the neighborhood poverty exposure index does not significantly improve the fit between the model and the data (Wald $\chi^2 = .31$, $p = .58$). Accordingly, the model provides no evidence that exposure to neighborhood poverty substantially mediates the effect of Hispanic residential isolation.

Model 3 adjusts the estimated effect of Hispanic residential isolation by controlling for individual-level maternal risk factors. Unlike in the models for black mothers, controlling for these characteristics and behaviors leaves the estimated association between residential isolation and very preterm birth unchanged compared to model 1. We also estimated additional model specifications with various subsets of the individual-level variables shown in the table (not shown). These models suggest that maternal ethnicity, age, years of education, and marital status account for a relatively small portion of the estimated effect of Hispanic residential isolation. Controlling for these characteristics decreased the logit coefficient for residential isolation by about 20%. However, controlling for maternal health conditions and prenatal care utilization increased the size of this coefficient back to the level reported in the table for model 3.

Lastly, model 4 adds an interaction term for residential isolation and mother's nativity. Even more clearly than in the case of black mothers, the model provides no evidence of a

significant difference in the effects of residential isolation on the risk of very preterm birth among immigrant vs. US-born Hispanic mothers (Wald $\chi^2 = .09$, $p = .77$). Accordingly, the model provides no support for the hypothesis suggested by assimilation theory, which predicted that residential isolation would be more strongly positively associated with very preterm birth among US-born than among immigrant Hispanic women.

As noted above, we replicated the same set of analyses for both black and Hispanic mothers using very low birthweight as the dependent outcome in place of very preterm birth (not shown). For black mothers, the results were substantively similar, but with one important difference. Models 1 through 3 produced substantively identical results, with the exact same coefficient for black residential isolation. These results suggest that the results for these models presented in Table 1 are unlikely to reflect measurement error associated with our indicator of very preterm birth. However, the interaction term in model 4 was statistically significant with very low birthweight as the dependent variable. Accordingly, these results suggest that residential isolation increases the odds of very low birthweight to a substantially greater extent among black immigrant mothers than among African American women. For Hispanic mothers, the models estimated with very low birthweight produced very different results. In particular, the logit coefficients for Hispanic residential isolation were consistently only about two thirds as large as those presented in Table 2 and were not statistically significant ($p \approx .14$).

Discussion

The central finding of this study is that metropolitan residential isolation is positively associated with very preterm birth among both black and Hispanic mothers, even after adjusting for several individual-level maternal risk factors, other metropolitan area characteristics, and unobserved

heterogeneity between metropolitan areas. While the positive association between metropolitan residential segregation and poor birth outcomes among black women is well established in the literature, only one prior study has documented an association between metropolitan residential segregation and birth outcomes among Hispanic women. As noted above, Osypuk, Bates and Acevedo-Garcia's (2010) analysis found a modest negative association between exposure to Mexican ethnic enclaves and birthweight among women of Mexican ancestry, but only among those born in the United States, not among Mexican immigrants. Moreover, it was unclear from their study whether this modest association was sufficient to substantially affect the risk of seriously adverse birth outcomes such as very preterm birth that are closely linked to infant mortality. Conversely, the present study suggests that Hispanic residential isolation is associated with an increased risk of very preterm birth among both immigrant and US-born Hispanic women.

However, there are at least two important caveats that should be borne in mind in connection with this study's central finding. First, the analysis presented here found no evidence that the effects of residential isolation on very preterm birth were mediated by exposure to neighborhood poverty among either black or Hispanic mothers. Given the pronounced influence of what Morenoff and Lynch (2004) have dubbed the "poverty paradigm" in research on the effects of geographic context on birth outcomes, this result is somewhat surprising. As we suggested in the introductory section of this article, one possible explanation for this finding is that the level of metropolitan residential segregation functions as a proxy for the pervasiveness of institutionalized and/or interpersonal racism in the metropolitan areas where black mothers reside. Prior research has established that perceived racism is positively associated with both black residential isolation and poor birth outcomes among black women. However, this

explanation remains largely unexplored for Hispanic women. Some evidence does suggest that racism contributes to Hispanic residential isolation, though most scholars suggest it plays a smaller role than in perpetuating black-white residential segregation. Less is known about whether or how perceived racism contributes to poor birth outcomes among Hispanic women. Accordingly, this issue merits further research.

Second, the results of our analysis of poor birth outcomes among Hispanic women were not robust across different dependent measures. Specifically, the analysis focused on very preterm birth suggested that Hispanic residential isolation was substantially positively associated with poor birth outcomes, while the analysis focused on very low birthweight did not. One possibility is that the results of our analysis of very preterm birth among Hispanic women were driven by measurement error associated with estimates of gestational age. As alluded to above, however, two of the key factors that contribute to this measurement error, unplanned pregnancies and late entry into prenatal care, substantially increase the risk of preterm birth (Behrman & Butler, 2007). Accordingly, one would expect this measurement error to lead to a conservative bias in the estimated association between residential isolation and very preterm birth. Alternatively, the weaker association between residential isolation and very low birthweight may reflect real differences in the structural, psychosocial and/or biological elements of the processes that generate very preterm births and moderately preterm infants that are born small for their gestational age.

One additional and unexpected finding that emerged from this study was that nativity moderates the relationship between residential isolation and seriously adverse birth outcomes, but only among black, not among Hispanic women. To be sure, the models predicting very preterm birth among black women did not produce evidence of statistically significant difference

in the association between residential isolation and this outcome when comparing immigrant with US-born black mothers. However, lack of statistical significance should not be given undue weight with the data examined here, given that they comprise a census of the entire population. While the apparent difference between immigrant and US-born black women could still reflect stochastic processes or measurement error, the finding of a statistically significant difference in the effect of black residential isolation on very low birthweight suggests that this difference may indeed be real and substantively important. Indeed, one valid interpretation of this latter finding is that living in a metropolitan area where black residents typically live in predominantly black neighborhoods undermines the protective effect of immigrant status among black mothers.

Conclusion

Given the very different results obtained in this study for Hispanic women using different measures of adverse birth outcomes, we do not believe that strong conclusions about the adverse effects of Hispanic residential isolation on birth outcomes are warranted. However, this study remains the first to produce suggestive evidence that residential isolation may have a deleterious influence on birth outcomes among Hispanic women, regardless of nativity. Moreover, the lack of evidence of a mediating role for exposure to neighborhood poverty among either black or Hispanic women suggests that future research should explore alternative explanations for both the already documented association between residential segregation and poor birth outcomes among black women and the more complex findings on this relationship among Hispanic women. Research focused on the role of racism as a contributing factor to both residential isolation and poor birth outcomes among each of these racial-ethnic groups may prove a fruitful avenue for deepening our understanding of these findings.

[1] The figures exclude metropolitan areas in which there were fewer than 350 total births to mothers in the focal group (blacks or Hispanics). In areas with small numbers of births to black or Hispanic mothers, stochastic variation affecting a small number of birth outcomes may have a pronounced influence on the observed rate (Kramer & Hogue, 2008).

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Figure 1: Distribution of Metropolitan-Level Very Preterm Birth Rates

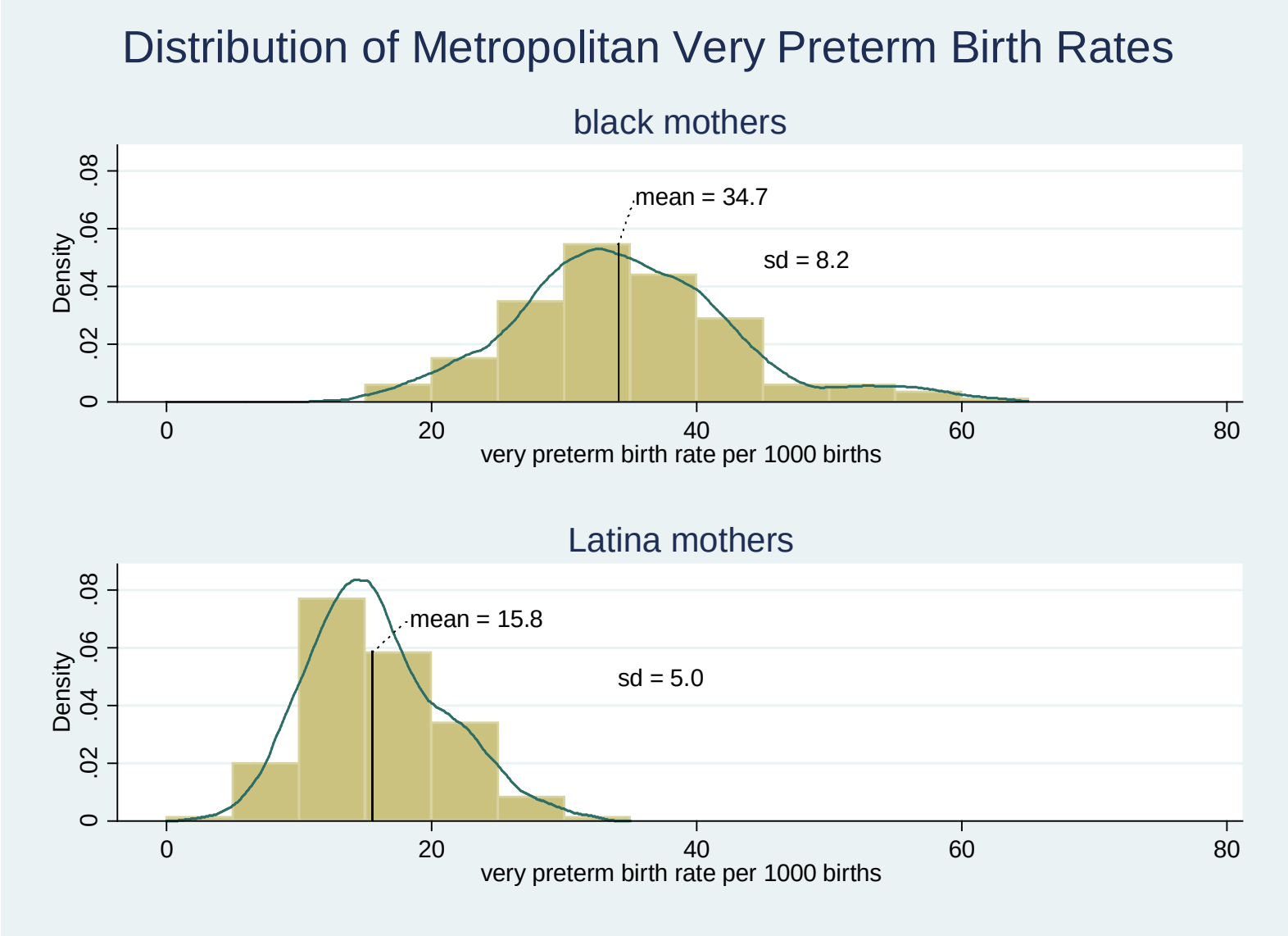

Figure 2: Metropolitan VPTB Rates for Black Mothers by Level of Residential Isolation

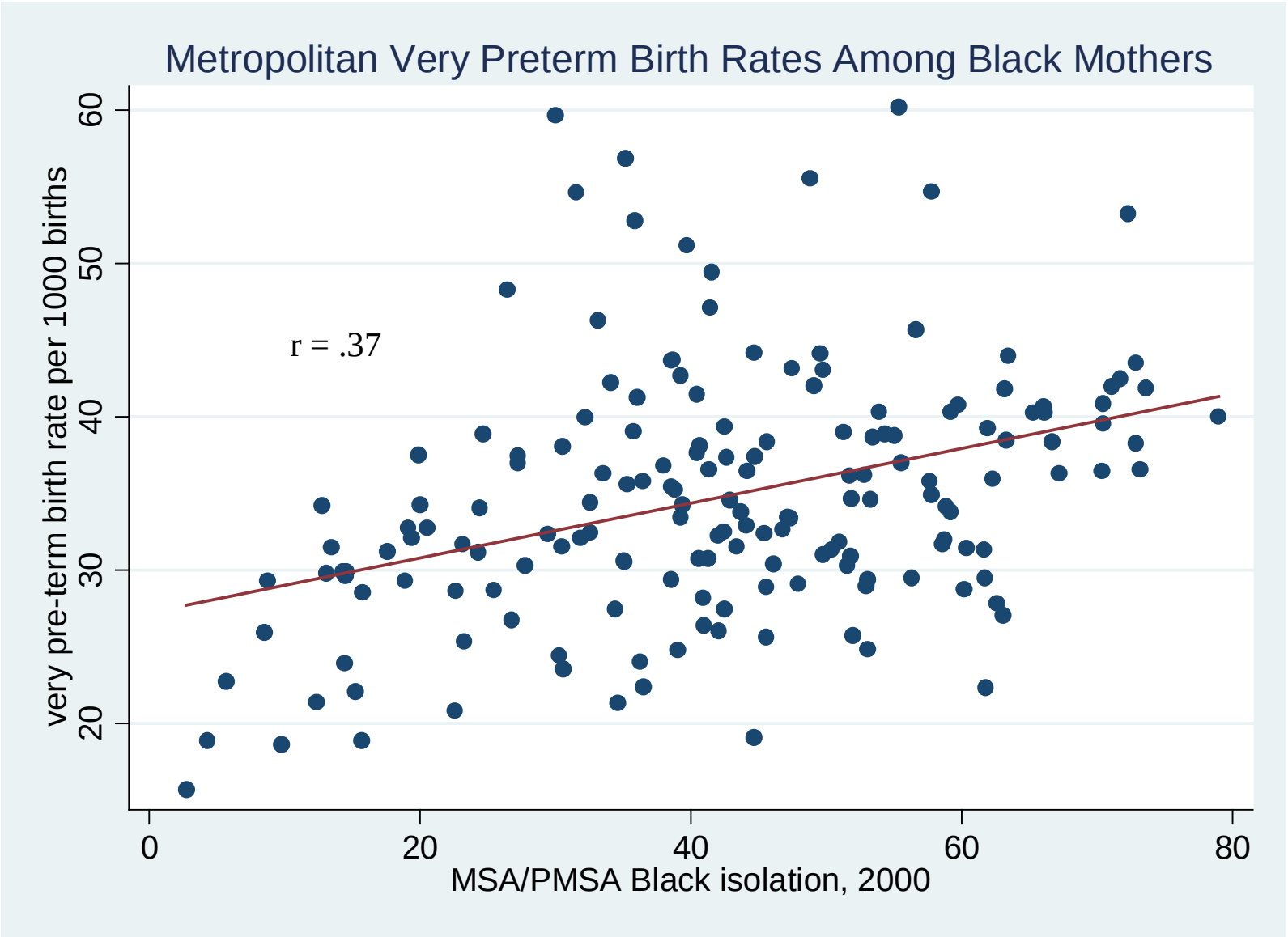

Figure 3: Metropolitan VPTB Rates for Hispanic Mothers by Level of Residential Isolation

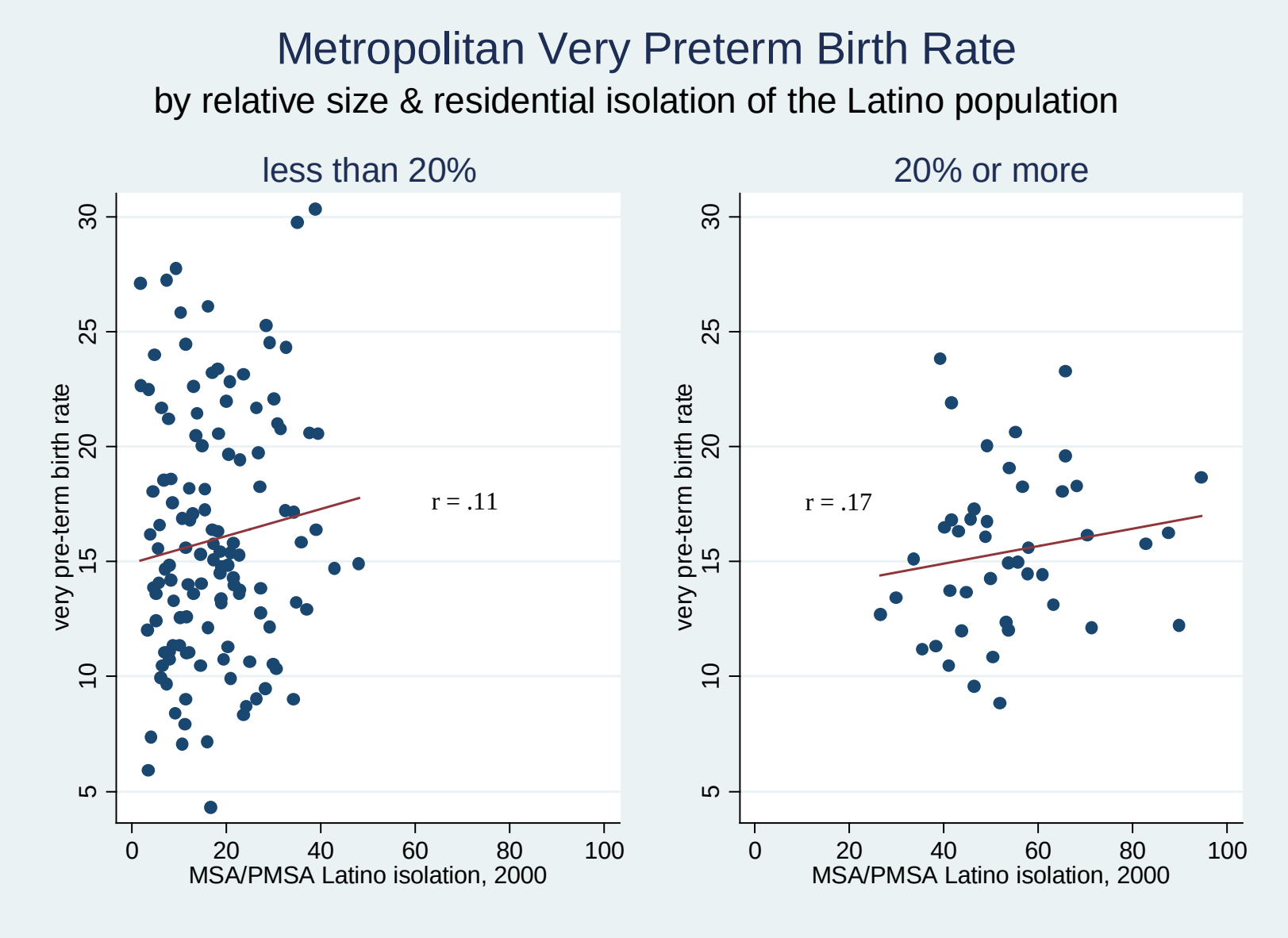

Table 1: Random Intercept Models Predicting Very Preterm Birth among Black Mothers

	Model 1		Model 2		Model 3		Model 4	
	b	s.e.	b	s.e.	b	s.e.	b	s.e.
Isolation	.007***	.002	.008***	.002	.004*	.002	.003†	.002
Isolation X foreign-born							.003	.002
Metro. % Blacks	-.003	.003	-.003	.003	-.001	.003	-.001	.003
Metro. Black poverty rate	-.001	.004	.003	.006	-.004	.004	-.004	.004
Metro. log population	-.054**	.019	-.052**	.019	-.025	.021	-.025	.021
Metro. median HH income	-.004	.004	.000	.000	.000	.000	.000	.000
% 12 years education	-.009	.006	-.010	.006	-.006	.007	-.006	.007
% 13-15 years education	-.015	.017	-.008†	.005	-.013**	.005	-.013*	.005
% 16+ years education	-.006	.005	-.007	.005	-.005	.005	-.005	.005
Infant sex	-.015	.017	-.015	.017	-.010	.017	-.010	.017
Poverty exposure			-.007	.009				
Age under 15					.607***	.096	.607***	.096
Age 15-19					.051	.033	.051	.033
Age 20-24					-.112***	.026	-.112***	.026
Age 30-34					.232***	.029	.232***	.029
Age 35-39					.351***	.034	.351***	.034
Age over 39					.468***	.054	.467***	.054
Foreign born					-.218***	.032	-.375**	.110
Married					-.256***	.023	-.256***	.023
Educ. = 12 years					-.075**	.024	-.075**	.024
Educ. = 13 – 15 years					-.195***	.028	-.195***	.028
Educ. > 15 years					-.295***	.037	-.295***	.037
Prior preterm birth					1.119***	.043	1.118***	.043
# of prior births					-.045***	.007	-.045***	.007
Smoked					.214***	.032	.214***	.032
Missing smoke					.179***	.051	.178**	.051
Drank					.437***	.090	.438***	.090
Missing drank					-.204***	.038	-.204***	.038
Chronic hypertension					.750***	.044	.750***	.044
Pregnancy-related hypertension					.669***	.032	.669***	.032
Eclampsia					1.288***	.074	1.288***	.073
Inadequate prenatal care					1.077***	.033	1.077***	.033
Intermediate prenatal care					-.206***	.050	-.206***	.050
Adequate plus prenatal care					1.712***	.028	1.712***	.028
Prenatal care missing					1.494***	.040	1.494***	.040
Constant	-2.147***	.544	-2.054***	0.554	-3.439***	.586	-3.479***	.584
ρ	.003		.003		.004		.004	

N = 465,271; *** p<0.01, ** p<0.05, * p<0.1

Table 2: Random Intercept Models Predicting Very Preterm Birth among Hispanic Mothers

	Model 1		Model 2		Model 3		Model 4	
	b	s.e.	b	s.e.	b	s.e.	b	s.e.
Isolation	.010**	.003	.009**	.003	.010**	.003	.010**	.003
Isolation X foreign-born							.000	.001
Metro. % Latinos	-.005	.004	-.005	.004	-.008*	.004	-.008†	.004
Metro. Latino poverty rate	.004	.004	.000	.007	-.006	.005	-.006	.005
Metro. log population	-.040*	.018	-.042*	.018	-.054**	.019	-.056**	.020
Metro. median HH income	.006†	.003	.006	.004	.001	.003	.001	.004
% 12 years education	.037***	.008	.037***	.008	.009	.009	.009	.009
% 13-15 years education	-.002	.006	-.002	.006	-.010	.007	-.009	.007
% 16+ years of education	.015*	.006	.016*	.006	-.002	.007	-.002	.007
Infant sex	-.166***	.019	-.166***	.019	-.144***	.020	-.144***	.020
Poverty exposure			.005	.010				
Puerto Rican					.232***	.042	.234***	.043
Cuban					-.177†	.092	-.177†	.092
Central/South American					.041	.033	.041	.033
Other/Unknown Hispanic					-.082	.051	-.083	.051
Age under 15					.904***	.128	.904***	.128
Age 15-19					.270***	.035	.270***	.035
Age 20-24					.031	.029	.031	.029
Age 30-34					.174***	.031	.174***	.031
Age 35-39					.327***	.038	.327***	.038
Age over 39					.550***	.060	.550***	.060
Foreign born					-.081**	.023	-.089*	.037
Married					-.278***	.022	-.278***	.022
Educ. = 12 years					-.080**	.024	-.080**	.024
Educ. = 13 - 15 years					-.151***	.033	-.152***	.033
Educ. > 15 years					-.383***	.045	-.383***	.045
Prior preterm birth					1.278***	.060	1.278***	.060
# of prior births					-.005	.009	-.005	.009
Smoked					.233***	.063	.233***	.063
Missing smoke					.047	.067	.048	.067
Drank					.104	.178	.103	.178
Missing drank					-.186**	.055	-.186**	.055
Chronic hypertension					1.187***	.074	1.187***	.074
Pregnancy-related hypertension					.903***	.039	.903***	.039
Eclampsia					1.322***	.094	1.322***	.094
Inadequate prenatal care					1.293***	.038	1.294***	.038
Intermediate prenatal care					-.237***	.058	-.237***	.058
Adequate plus prenatal care					2.046***	.032	2.046***	.032
Prenatal care missing					1.859***	.047	1.859***	.047
Constant	-5.083***	.696	-5.110***	.699	-4.503***	.754	-4.514***	.755
ρ	.004		.004		.006		.006	

N = 791,855; *** p<0.01, ** p<0.05, * p<0.1