Introduction

In the past 15 years, there has been a steep increase in the number of immigration-related laws introduced and passed in state legislatures (Morse et al., 2012; Philbin, Flake, Hatzenbuehler, & Hirsch, 2016). Though only occasionally explicitly related to health (for example, by restricting access to Medicaid or WIC benefits), these policies may have pervasive effects on the health of immigrants and their families (Hardy et al., 2012). As reviewed by Philbin (2018) and Wallace (2018), immigration-related laws may affect health through restricting or expanding access to public institutions, improving or worsening material conditions or through causing chronic stress through structural racism (Philbin et al., 2016; Wallace, Young, Rodríguez, & Brindis, 2019).

The pathway linking immigration policies to chronic stress and structural racism is distinct. Unlike changes in access to services or material conditions, laws that increase chronic stress likely affect both immigrants and individuals who identify with immigrant groups (due to ancestry or ethnic identity) or who are perceived as members of immigrant groups. Limited existing research supports this idea. Two recent papers have shown that living in a state with more restrictive immigration policies is associated with increased days of poor mental health and increased perceived discrimination for both US-born and foreign-born Hispanic residents (Almeida, Biello, Pedraza, Wintner, & Viruell-Fuentes, 2016; Hatzenbuehler et al., 2017). To our knowledge, only one paper examines how immigration policies may impact health by increasing chronic stress levels. Torche and Sirois found a decline in birthweight among foreign-born Latina women in Arizona who were pregnant during the debates over the passage of SB1070, a particularly notorious restrictive immigration law. Given that there was no reduction

in access to care or economic opportunity before the passage of the law, the authors hypothesized the decline was likely due to chronic stress (Torche & Sirois, 2018). Further study is needed on how immigration policies may impact objective health outcomes by causing structural racism and increasing chronic stress.

Many hypothesize that chronic stress is a determinant of perinatal health, including very preterm birth (Kramer, Hogue, Dunlop, & Menon, 2011; Kramer & Hogue, 2009; Lorch & Enlow, 2016; Lu & Halfon, 2003; Rich-Edwards & Grizzard, 2005). Very preterm birth (VPTB) is a rare outcome that greatly increases risk of infant mortality and long term morbidities (Saigal & Doyle, 2008). It is usually defined as live birth before 32 completed weeks gestation. Experiences of contextual stress, including segregation and neighborhood disorder, have been linked to elevated risk of VPTB, though the causal mechanisms are yet unclear (Kramer, Cooper, Drews-Botsch, Waller, & Hogue, 2010). Chronic stress may increase risk of VPTB through weathering of physiologic systems, changes in immune or neuroendocrine functions or maladaptive behavior (e.g., smoking or obesogenic diet) (Kramer & Hogue, 2009).

Though previous research has primarily focused on adverse effects of immigration-related laws, individual laws contribute to a complex immigration policy climate that may be supportive or restrictive as a whole. Immigration-related laws may support immigrants (e.g., by expanding access to benefits or providing support for resettlement) or make life more challenging for immigrants (e.g., by restricting access to benefits such as the Women, Infants, and Children (WIC) program, facilitating police harassment or targeting industries in which primarily immigrants are employed). Only rarely do immigrants in a place experience only one

law at a time. Immigration policy climate refers to the total experience of all immigration policies in a given place and time, capturing the net effect of all laws in place at a time (Pham & Pham, 2014; Pham & Pham, 2017). Overall immigration policy climate refers to a net effect that may be more hostile (restrictive) or welcoming (supportive) towards immigrants.

The Immigration Climate Index (ICI) is a continuous measure that represents the total effect of immigration policies in place for a state in a given year. Briefly, each new policy enacted is assigned a value from -4 to 4 by evaluating the severity of impact on the lives of immigrants (1, negligible impact to 4, large impact), assigned a negative value if restrictive or a positive value if supportive and weighted by the proportion of the state population that it would legally affect (if not for the entire state). An example of a supportive policy is allocating funds for English as a second language education and an example of a restrictive policy is making driving without a driver's license a jail-worthy offense in a state where undocumented immigrants are not allowed to get licenses. All policies in place for a given year (newly passed and already in place) are summed to give the cumulative ICI. A cumulative ICI that is below zero represents an immigration climate that is, on average, restrictive, whereas a cumulative ICI above zero represents a climate that is, on average, supportive. The measure only includes policies enacted starting in 2005, assigning all states before that year a value of zero. The index is calculated each year, 2005-2016, and ranges from -788.9 to 684.2 (mean: -48.97, SD: 122.61).

As described, evidence is limited on whether and how immigration policies affect immigrant health generally, or chronic stress-mediated health specifically. The goal of this analysis is to explore the role of immigration policy climate on risk of very preterm birth among

Hispanic mothers by estimating the effect of living in a state with a more restrictive immigration policy climate on very preterm birth among Hispanic women. This analysis adds to our understanding by considering the impact of immigration policy climate on very preterm birth in both US-born and foreign-born Hispanics across the United States.

Theoretical Framework

Hispanic women, as a group, demonstrate rates of adverse birth outcomes similar to or even lower than non-Hispanic white women, despite socioeconomic disadvantage (Beccera, 1991; Martin, Hamilton, Osterman, Driscoll, & Drake, 2018; Martin, Hamilton, Osterman, Driscoll, & Mathews, 2017b). This oft-cited 'Hispanic Paradox' is strongest among foreign-born Hispanic women and declines among second and third generation immigrants (de la Rosa, 2002). The paradox has not been consistent across time or geography, supporting a role for context in the apparent pattern (El-Sayed, Paczkowski, March, & Galea, 2014; Fishman, Morgan, & Hummer, 2018). There have been many proposed explanations for the paradox, including a proposal by Viruell-Fuentes (2012) that recently arrived immigrants are buffered from the toxic effects of othering and discrimination experienced by minority groups who are more closely tied to mainstream US culture (Viruell-Fuentes, Miranda, & Abdulrahim, 2012; Viruell-Fuentes, Morenoff, Williams, & House, 2013). This buffering may come, in part, from interpersonal and community-level systems of social support (Bostean, Andrade, & Viruell-Fuentes, 2018; Coburn, Gonzales, Luecken, & Crnic, 2016). Undue focus on the overall pattern of the paradox may obscure within-group variation that represents sources of risk or protective factors. A nuanced understanding of how risk in VPTB varies across subgroups of Hispanic women, geographically and over time, may offer insight into the possible roles of context in determining perinatal risk.

Immigration policy climate is one of many potential risk determinants occurring in the lives of Hispanic women before and during their pregnancies. These include stress-promoting and stress-reducing factors from multiple sources and at multiple levels, including historical and current economic and social forces, policies at the national, state, and county levels, community level challenges and resources as well as familial and individual supports. In order to conceptualize these interconnected factors, we have adapted Krieger's Ecosocial framework to this context (Krieger, 2001; Krieger, 1994). As shown in Figure 1, stress promoting factors and protective buffers arise from individual characteristics and interpersonal experiences, as well as national and global contexts (Figure 1).

The Ecosocial framework allows for simultaneous consideration of factors at multiple levels that may have direct or indirect effects on women's health. For example, in the case of immigration policy, policies may indirectly affect women's health through restricting access to work and material resources or health care. However, the same policies may also directly impact women's health by causing stress and anxiety. The Ecosocial framework allows us to consider immediate, possibly direct, effects of national and geographic level factors traditionally considered distal. Applying the Ecosocial framework to these data gives a wider context in which to place our results from an analysis of cross-sectional data from birth certificates.

For the purposes of this project, we focused on a set of individual, interpersonal, local and state level factors. Stress is a complex phenomenon, with a woman's lived experience dependent on individual perceptions, history and vulnerabilities as well as changing exogenous

factors (Epel et al., 2018). Many studies have measured maternal prenatal or preconception stress using perceived stress scales or life event scales (Graignic-Philippe, Dayan, Chokron, Jacquet, & Tordjman, 2014). While useful, these scales often miss effects of cumulative, ongoing stressors present in women's lives, such as systems of oppression, poverty or potentially immigration climate, which women may not associate with stress or a single event (Epel et al., 2018).

Our framework considers only exogenous stress-producing factors: high-intensity immigration enforcement, restrictive immigration policy climate and county level poverty. We recognize these are only three of the ways in which stress may be produced in the lives of Hispanic women. Simultaneously, we consider the role of social support at two levels as protective buffers against the negative effects of stress: residence in an ethnic enclave and partner support. Situating these analyses inside the broader Ecosocial framework allows us to recognize the gaps in what we are not measuring, to consider a wider context and to theorize further about how these stressors may be embodied in the lives of Hispanic women.

Methods

Data

Using information on maternal county of residence at delivery, we linked data from the 2005-2016 US live birth file to data on state and county characteristics from the American Community Survey, data on state and county level immigration policies from the Department of Homeland Security, and the Immigrant Climate Index (ICI) database assembled by Pham and Pham (Pham & Pham, 2018). We limited the primary analytic dataset to Hispanic women with information on gestational age and maternal place of birth. In addition, we excluded all records

for county/year combinations with fewer than 100 live births to Hispanic women for that county in that year. The final analytic dataset contained a total of 10,683,234 births to Hispanic mothers in 807 counties in 47 states from 2005-2016 (Figure 2).

Analysis

We fit a series of nested, generalized linear mixed models with very preterm birth (live birth before 32 completed weeks gestation) as the outcome and random effects for state and county. After a baseline or unconditional model (the 'empty model'), our first model included individual level predictors (parity, age and education) that may reflect some stress but generally represent conventional risk factors for very preterm birth. In the second model, we added relationship status, a variable representing a potential source of interpersonal stress or social support. Relationship status is operationalized here as a three-level variable indicating whether women were married at the time of delivery, unmarried but with information on the baby's father on the birth certificate or unmarried without any information on the baby's father on the birth certificate (Desenclos, Scaggs, & Wroten, 1992; Gaudino, Jenkins, & Rochat, 1999; Sullivan, Raley, Hummer, & Schiefelbein, 2012). In the third model, we added information on women's immigration histories by adding indicators for US-born v. foreign-born and specific Hispanic origin. Though these variables are imprecise measures of immigration history, we believe they represent both individual factors and information about the social context in which women grew up and currently live.

In the fourth model, we added information about stress and social support promoting factors in the local (county-level) context: poverty, percent Hispanic (indicating ethnic density),

whether the county was urban or rural and whether any police jurisdiction in the county (either county wide or municipal) participated in a 287(g) agreement with Immigrations Customs Enforcement (ICE). 287(g) agreements are agreements between police departments and ICE that allow local police to participate in immigration enforcement activities (American Immigration Council, 2017). Here we are considering having a 287(g) agreement in place as an indicator of county-level enforcement intensity, as have previous authors (Potochnick, Chen, & Perreira, 2016). In our fifth and final model, we included information on state level context, specifically year, state-level immigration policy climate and ratio of estimated number of undocumented residents to the total foreign-born population (Passel & Cohn, 2016). We used one-year lagged Immigration Climate Index (ICI) based on the hypothesis that this would represent the exposure immediately prior to and during the pregnancy. We calculated the ratio of estimated undocumented population to total foreign-born population using state level estimates of the number of foreign-born residents from the American Community Survey and estimates of the number of undocumented individuals at the state level as produced by Passel & Cohn for the Pew Research Center (Passel & Cohn, 2016). We used a two-year lagged undocumented ratio to represent the percent of undocumented residents the year prior to the 1-year lagged Immigration Climate Index, as policies may be passed in response to growth in the size of the undocumented population (Pham & Van, 2014).

We operationalized maternal age using a linear and quadratic term to reflect the j-shaped relationship between maternal age and VPTB risk (Geronimus, 1992; Wilcox, 2010) . We dichotomized maternal education into less than high school education versus high school education or more and parity into nulliparous and multiparous. We represented maternal nativity

as US-born or foreign-born and specific Hispanic origin as a five-category variable (Mexican, Puerto Rican, Cuban, Central/South American, Other Hispanic). The percent of families below the federal poverty level represented county-level poverty and we categorized it into quartiles. We used the percent of the county's population that was Hispanic to represent ethnic density and categorized it into quartiles. For both county level poverty, and percent Hispanic, we use 5-year estimates. For example, for years 2005-2009, the 5-year 2005-2009 estimates were used.

In calculating the ratio of estimated number of undocumented residents to total foreign-born population, we used 1-year estimates of counts of the state foreign-born population from the American Community Survey. For estimates of the 2003 and 2004 foreign-born population, the 2000 census estimate was used, as 1-year estimates were not available for those years. Four states (Wyoming, North Dakota, South Dakota and Montana) did not have estimated numbers of undocumented residents due to sparse numbers. For analytic purposes, we assumed that these states had the median percent of undocumented residents out of all states. We divided the two-year lagged undocumented ratio into quartiles.

To explore potential geographic variation in risk of VPTB, we calculated the median odds ratio (mOR) for each model to quantify unexplained between-state and between-county variation in risk (Larsen & Merlo, 2005a). The median odds ratio represents the median value for all possible odds ratios comparing VPTB in two different counties or states. Variance decomposition methods allow us to quantify both the impact of known, measured factors at multiple levels as well as unknown, unmeasured factors (Merlo et al., 2006). Given that VPTB is a dichotomous outcome, this is more appropriate than measures like the pseudo-interclass

correlation coefficient which assumes a constant variance at the individual level (Larsen & Merlo, 2005b).

Based on the cumulative range of the ICI in the analytic sample of women, we divided the ICI and one and two year lagged ICIs into quintiles (1^{st}: $-685 \leq ICI < -60.5$; 2^{nd}: $-60.5 \leq ICI < -4.4$; 3^{rd}: $-4.4 \leq ICI < 0$; 4^{th}: $0 \leq ICI < 42.0$; 5^{th}: $42.0 \leq ICI < 684$). We calculated odds ratios comparing the odds of VPTB in states in the lowest quintile of ICI (most restrictive) to each of the other quintiles. We also examined maternal place of birth (US-born v. foreign-born) as a potential effect modifier of the association between state immigration policy climate and VPTB by including an interaction term between maternal place of birth and ICI quintiles. In order to assess effect modification on the additive scale, we fit linear risk models with random effects for state and county and calculated risk differences comparing risk of VPTB across ICI quintiles.

Sensitivity Analyses

We performed a number of sensitivity analyses. One year may not be the appropriate lag for ICI. We also conducted analyses using two-year lagged ICI and current-year ICI. Two-year lagged ICI would capture the environment prior to conception, if the mother had been living in the state for at least two years prior to delivery. Current-year ICI might reflect the environment prior to the enactment of policies, potentially during the time in which they were debated and passed, reflecting changes in immigrant-related sentiment or anxiety about the policies themselves. As the ICI is correlated across years, we would not expect changes in the direction of association based on lag time but potentially changes in the strength of association.

Finally, we conducted a negative control analysis, in which we repeated the final model estimating the effect of living in a state with a more restrictive immigration climate using populations of non-Hispanic white mothers and non-Hispanic black mothers. We repeated the exact model except specific Hispanic origin was excluded. In order to consider heterogeneity on the multiplicative and additive scales, we fit both logistic and linear risk models. If the effects were similar, this would suggest that the observed effect was not due to the ICI but rather some other, geographically varying factor affecting the health of both Hispanic and non-Hispanic women. To create this dataset, we began with only the same counties included in the analytic dataset for Hispanic women. Then, we excluded counties with fewer than 100 births for a given county/year combination for non-Hispanic white and non-Hispanic black women, separately. The final analytic dataset contained 26,904,048 births in 807 counties in 47 states for non-Hispanic white women and 6,024,891 births in 484 counties in 44 states for non-Hispanic black women.

Results

In the analytic dataset, 1.5% of births to Hispanic mothers were very preterm and 10.6% were preterm (<37 completed weeks gestation) (Table 1). Mothers who lived in states with the most restrictive immigration climates (quintile 1 of ICI) were more likely to have a very preterm (1.6% v. 1.3%) or preterm birth (11.2% v. 8.7%) than those who lived in the most supportive immigration climates (quintile 5). Maternal characteristics (age, specific Hispanic origin, nativity, education, parity) were consistent across quintiles 1 and 5. Mothers living in states with more restrictive immigration climates were more likely to live in a rural county and live in a

county with a 287(g) program in place. The average two-year lagged proportion of estimated undocumented residents out of the foreign-born population was higher in states with a lower (more restrictive) ICI (0.4 v. 0.2). Mothers living in states with more restrictive immigration climates lived in counties, on average, with a lower percent foreign-born residents (18.2% v. 28.2%). The percent of Hispanic residents, percent of families living below the federal poverty line, and percent of residents without a high school education were similar in states in the highest and lowest quintiles of ICI.

The ICI changed dramatically over the twelve included years. All states began at a neutral ICI of zero in 2005, when scoring began, which falls in the fourth quintile of the ICI. Between 2005 and 2010, there was limited legislative activity and only a few states moved out of the third or fourth quintiles of ICI. However, between 2010 and 2016, states showed dramatic annual shifts, with shifts of up to 50 points over a 1 year period (representing over 12 new policies passed in that year). While many states changed quintiles, going from neutral to mildly negative to very negative or neutral to positive, switches from a negative to a positive trajectory over the twelve years were rare (<1% of all annual changes). Arizona and California were the negative and positive outliers, respectively, in every included year. Figure 3 shows trajectories for 5 example states.

The proportion of unexplained variance at the state level remained constant across the nested models (Table 2). The median odds ratio (mOR) for state was 1.10 for the empty and final models, meaning that out of all possible two-state comparisons, the median odds of very preterm birth were 10% higher in the riskier of the two. The proportion of unexplained variance at the

county level declined only slightly across the nested models (mOR declined from 1.14 to 1.11). The largest change in the county median odds ratio occurred after the addition of maternal nativity and specific Hispanic ethnicity to the model (1.5% decline). This suggests that the majority of unexplained variance in VPTB among Hispanic women was at the individual level.

In a model controlling for individual and county characteristics, as well as year and proportion of foreign-born residents who were undocumented, women living in states in the lowest (most restrictive) quintile of one-year lagged ICI had 7% higher odds of delivering a very preterm infant compared to women living in states in the highest quintile of one-year lagged ICI (aOR: 1.07 (1.04 – 1.10)) (Table 3). There was some evidence of a dose response in the effect for all Hispanic mothers, with the strongest observed association comparing the most restrictive quintile of ICI (1) to the supportive quintiles (4,5) and smaller associations comparing the most restrictive to a neutral quintile (3) or restrictive but less restrictive (2). For US-born women, the risk was not elevated in quintile 1 compared to quintile 2 or 3. However, for foreign-born women, risk remained elevated comparing quintile 1 to quintiles 2-5 (Table 3, Figure 4). The association was consistent when using a one-year, two-year or no-lag ICI. (Table 4).

Our final model (Table 5) incorporates stress-promoters and buffers in the lives of Hispanic women as reflected in our adaptation of the Ecosocial framework. Relationship status showed the strongest association with very preterm birth risk. Compared to unmarried women with no paternal information on the birth certificate, married women had a 40% lower odds of very preterm birth (aOR: 0.60 (0.59 – 0.60) and unmarried women with the baby's father's information had a 24% lower odds of very preterm birth (aOR: 0.76 (0.75 – 0.77)). Ethnic

density, a community level social support indicator, had no effect on the odds of very preterm birth. Of hypothesized stress-promoting factors, only living in a county with the highest percentage of families below the federal poverty line (highest quartile compared to lowest quartile) increased odds of very preterm birth. Living in a county with a 287(g) program in place or a state in the highest quartile of undocumented to all foreign-born ratio had no effect on very preterm risk among Hispanic mothers. Consistent with previous research on the Hispanic paradox, US-born women had a higher odds of very preterm birth (aOR: 1.11 (1.09 – 1.12)).

Replication of the final model among non-Hispanic white mothers and non-Hispanic black mothers showed distinct associations (Figure 4). Among all Hispanic women, living in a state in the lowest quintile of one-year lagged ICI resulted in an increased risk of very preterm birth of 0.8 additional very preterm births per 1000 live births (aRD: 0.0008 (0.0004 – 0.0013)). Among all non-Hispanic white mothers, living in a state in the lowest quintile of one-year lagged ICI resulted in an increase of 0.3 additional very preterm births per 1000 live births (aRD: 0.0003 (0.00008 – 0.0005); aOR: 1.03 (1.01 - 1.05)) compared to living in the highest quintile of one-year lagged ICI. When comparing risk across quintiles 1 and 3 or 1 and 2, there was no association. Among non-Hispanic black mothers, there was no association between living in a state in the lowest quintile of one-year lagged ICI and very preterm birth or any other quintile comparison. The observed associations were distinct across maternal nativity groups, with the largest differences in the associations among foreign-born mothers. For US-born Hispanic and non-Hispanic white mothers, the pattern of associations was similar, with smaller associations among non-Hispanic white mothers. We conducted two other sensitivity analyses. In a sensitivity analysis (not presented), including observations missing education and imputing maternal

education at universally high or universally low values did not change our effect estimates. For analytic purposes, we imputed the median proportion undocumented in four states with missing values for estimated number of undocumented residents. To test this assumption, we reran the analyses with the 25th percentile and 75th percentile imputed instead. This did not change our results meaningfully (analysis not presented).

Discussion

Living in a state with more restrictive immigration policy climate was associated with a slight increase in the odds of very preterm birth, after controlling for individual, county and state level confounders. The results are consistent with the Ecosocial model as operationalized for these analyses. The model frames immigration policy climate as one of many factors associated with the health of Hispanic mothers and their infants. The immigration policy climate association was consistent across US-born and foreign-born Hispanic women, supporting the idea that restrictive immigration policies may affect not only immigrants but also those associated with or perceived as members of immigrant groups (Asad & Clair, 2018).

The slight increase in the odds of very preterm birth for mothers exposed prenatally to more restrictive immigration policy climates is also consistent with the moderate increase in odds of a low birth weight birth following a major immigration raid, the slight decrease in birthweight following debates over the passage of Arizona's SB1070, and other research on the impact of place-based chronic stressors on health outcomes (Michael R. Kramer et al., 2010; Novak, Geronimus, & Martinez-Cardoso, 2017; Torche & Sirois, 2018). The effect size of living in a state in the most restrictive quintile of immigration climate index on VPTB was

similar to that of living in a county with the highest proportion of families living below the federal poverty level in our model. This supports the idea that contextual level stressors produce slight but meaningful increases in risk for Hispanic mothers. In addition to the serious health implications for babies born very preterm, VPTB is a significant financial burden to families and health systems. Cost estimates vary, but the immediate medical cost of one very preterm birth is at least $46,400 and likely much higher (Behrman & Butler, 2007; Gilbert, Nesbitt, & Danielsen, 2003). Thus, even slight increases in the incidence of VPTB have enormous financial impacts at a population level. If the effects identified were causal, and if all states in the worst four quintiles had the ICI of the most supportive quintile, nationally we would expect 2,691 fewer very preterm births to Hispanic women per year, at a savings of $124,882,410 (based on 2016 births).

The observed association of immigration policy climate was similar across a two-year, one-year and no-lag model. This may be due to autocorrelation of context over time or suggest that the observed association may be a mix of the effects of anticipation of the passage of policies and experience of the policies. Additionally, anti-immigrant sentiment alone may elevate risk of adverse birth outcomes. Krieger and colleagues found an effect of anti-immigrant sentiment (operationalized as the time period before the 2016 United States presidential election) on birth outcomes among Latina women in New York City (Nancy Krieger, Huynh, Li, Waterman, & Van Wye, 2018). It may also reflect the fact that, while the ICI does change dramatically across years, only rarely do states switch between quintiles of ICI over a one year change.

To consider potential residual, geographically distributed confounding, we fit our final fully-specified model among non-Hispanic white and non-Hispanic black mothers. We did not observe a similar association among non-Hispanic black mothers, supporting our inference. Among all non-Hispanic white mothers and US-born non-Hispanic white mothers, a similar, weaker association was observed without the dose response pattern seen among Hispanic mothers. The reason for this may be residual confounding due to some state-varying factor that is associated with VPTB risk among both Hispanic and non-Hispanic white mothers. However, it is unclear what state-varying factor would not also affect non-Hispanic black mothers. It may be that white women living in states in the fifth, most supportive quintile of ICI (e.g., California, New York, Illinois, Connecticut) have access to greater resources or socioeconomic advantage compared to white women in the most restrictive quintile of ICI (e.g., Georgia, Arizona), accounting for the elevated risk in quintile 1 compared to quintile 5 observed among white women. The observed heterogeneity across foreign-born mothers may reflect the heterogeneity of non-Hispanic black and non-Hispanic white immigrant populations.

Our analysis has several limitations. First, birth certificates do not capture data on a number of key covariates at the individual level, including documentation status and length of time in the United States. Both of these variables would likely modify how Hispanic women would be impacted by immigration laws. Notably, in our variance decomposition analysis, the majority of unexplained variance was at the individual level, suggesting possible important unmeasured covariates at the individual level. Second, birth certificates have a number of known data issues, including a high percentage of missing data on certain variables and some misclassification. In our sample, some observations were missing information on nativity or

gestational age and were excluded prior to geographic exclusions (Figure 2). This could bias the results if the women excluded were systematically different. For example, there would be bias if women who had a very preterm birth were less likely to complete these areas on the birth certificate and more likely to live in states with restrictive immigration policy climates. Following those exclusions (nativity and gestational age), the only individual covariate missing in our sample was maternal education. Misclassification of gestational age and maternal ethnicity on the birth certificates was rare in available validation studies (Martin et al., 2013; Reichman & Schwartz-Soicher, 2007; Roohan et al., 2003). Third, the measure of immigration policy climate does not consider policies in place before 2005, assigning all states an index of zero in 2005, though some states may have already had restrictive or supportive policies in place (Van & Pham, 2017). As 2005 precedes the period of greatest activity for state-level legislative action on immigration, we do not expect this to have a significant effect on our analysis (Morse et al., 2012; Philbin et al., 2016). However, we recognize that policies in place prior to 2005 may have contributed to immigration policy climate in ways we are unable to capture using the Immigration Climate Index (ICI). Finally, birth certificates represent a cross-sectional view of the population and we cannot know how similar the populations in each state are across years. Over the 12 years included in the analytic dataset, the populations of Hispanic mothers in each state may have shifted, challenging our ability to compare across years within states. While adjusting for maternal nativity and specific ethnicity may capture some of this change, there are likely other changing factors that we were not able to capture which may influence risk. However, there is no evidence to suggest that changing demographics affect immigration climate beyond the proportion of undocumented residents, for which we have controlled.

Our analysis also offers several strengths. First, birth certificates are a census of births in the United States, capturing vulnerable populations of women who are unlikely to be included in population-based epidemiologic studies. Second, we use a comprehensive, time-varying measure of immigration policy climate that was developed by a legal expert and an economist. Though some subjective judgement is implied in the rating of policies for inclusion in the ICI, the subjectivity is likely not related to very preterm birth (or other health outcomes). This measure allowed us to consider the simultaneous, cumulative impact of multiple policies in place at one time, as they would be experienced. This adds to previous research which has considered only the associations with one policy or even the more comprehensive approach by Haztenbuehler et al. that considered 14 policies across 4 domains (Hatzenbuehler et al., 2017). Though we chose to categorize the ICI, our estimates were robust to categorization of ICI and consistent across decile and quartile categorizations (analyses not presented). Finally, the measures of stress we considered, immigration policy climate, immigration enforcement intensity and county level poverty, are exogenous factors that are potentially modifiable by policy action and not dependent on self-report or underlying individual factors.

The effect of immigration policy climate on the stress levels and health of Hispanic mothers is likely intertwined with the effect of anti-immigrant sentiment and immigration enforcement. Anti-immigrant sentiment, immigration enforcement and immigration policy are themselves intertwined (Flores, 2017). Further study is needed to disentangle these factors and to identify potentially protective interventions or strategies to prevent adverse birth outcomes among affected women. Immigration climate is ecologic in nature. However, the experience of stress from immigration policy climate is likely heterogeneous with some women affected more

than others due to individual, familial or geographic characteristics. In our analysis, we did not find meaningful additive effect heterogeneity across maternal nativity groups (US v. foreign-born) and were unable to consider legal status as a potential effect modifier. Future researchers should consider innovative ways to explore the pathways through which immigration policy climate may be associated with stress and health outcomes among Hispanic women. More information on Hispanic women's lived experiences of stress from immigration policies, enforcement and anti-immigrant sentiment will elucidate the role of immigration policy climate in increasing perinatal risk among US-born and foreign-born Hispanic women.

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Table 1. Maternal and place-based characteristics of 10,683,234 Hispanic women delivering a live born infant in 47 US states and 807 counties between 2005-2016

	ICI Quintile 1 (most restrictive) n=396,244	ICI Quintile 5 (most supportive) n=340,047	Total (with ICI q. 2 - 4) n=10,683,234
Maternal Characteristics	**% (n) or mean (SD)**	**% (n) or mean (SD)**	**% (n) or mean (SD)**
Maternal Age	26.8 (6.2)	27.5 (6.2)	26.9 (6.2)
Gestational Age	38.6 (2.4)	38.8 (2.2)	38.7 (2.3)
Birth Weight	3,277 (527.6)	3,323 (527.8)	3,299.2 (530.1)
Very Preterm	1.6 (35,976)	1.3 (29,439)	1.5 (160,270)
Preterm	11.2 (255,397)	8.7 (204,500)	10.6 (1,130,391)
Very Low Birthweight	0.9 (20,214)	0.8 (19,348)	0.9 (93,468)
Low birth weight	6.0 (137,529)	5.2 (121,679)	5.7 (606,269)
Specific Hispanic Origin			
Mexican	69.9 (1,595,571)	72.8 (1,704,970)	63.8 (6,818,865)
Puerto Rican	2.8 (63,831)	3.3 (78,316)	6.9 (739,501)
Cuban	1.2 (28,026)	0.4 (9,227)	1.9 (203,318)
Central/South American	11.1 (252,372)	10.7 (250,089)	15.3 (1,631,875)
Other/Unknown Hispanic	15.1 (344,087)	12.8 (298,884)	12.1 (1,289,675)
Primiparous	29.3 (669,964)	30.4 (711,423)	30.3 (3,237,675)
Relationship Status			
Married	49.7 (1,135,542)	46.4 (1,085,579)	47.6 (5,082,707)
Unmarried, w/ paternal info	38.0 (868,032)	45.7 (1,070,502)	41.1 (4,395,445)
Unmarried, w/o paternal info	12.3 (280,313)	7.9 (185,405)	11.3 (1,205,082)
Maternal Education			
8th grade or less	10.4 (236,780)	11.4 (267,602)	13.6 (1,451,853)
Some high school	22.1 (505,031)	21.7 (508,068)	23.3 (2,487,807)
High school grad	27.5 (627,763)	30.5 (713,672)	27.7 (2,957,279)
Some college/associates	20.4 (466,624)	23.3 (546,098)	19.2 (2,049,020)
College or more	9.6 (218,775)	9.8 (228,287)	9.2 (980,854)
Missing	10.0 (228,914)	3.3 (77,759)	7.1 (756,421)
Foreign-born	49.0 (1,118,175)	49.3 (1,154,195)	55.7 (5,947,589)
Place Based Measures			
% w/o High School Diploma	18.3 (8.5)	19.6 (6)	18.4 (7.4)
% Foreign-born	18.2 (9.1)	28.2 (8.1)	22.5 (11.4)
% Hispanic	37.7 (25.2)	38.8 (13.6)	33.5 (20.6)
% living below FPL	18.4 (6.5)	16.6 (4.8)	16.3 (6.0)
% on Public Assistance	2.1 (0.8)	4.1 (1.8)	2.9 (1.6)
Rural County at Delivery	7.1 (162,168)	0.8 (17,472)	4.9 (526,443)
Living in County w/ 287g	31.6 (721,648)	16.1 (375,816)	15.2 (1,618,030)
Est. ratio of undocumented to all foreign-born residents, state	0.4 (0.1)	0.2 (0)	0.3 (0.1)

ICI quintile 1= states with ICI < -60.5; ICI quintile 5= states with >42.0; ICI=Immigration Climate Index; w/=with; w/o=without; FPL=federal poverty level; Est.=estimated

Table 2. Variance Decomposition Results, very preterm birth risk, Nested Generalized Linear Mixed Models with random effects for state and county, births to Hispanic women in the United States, 2005-2016, n=10,683,234

		State		County	
Model	**Variables Included**	**Variance**	**MOR**	**Variance**	**MOR**
0	none	0.010	1.10	0.019	1.14
2	Relationship status, age, education, parity	0.011	1.10	0.019	1.14
3	Model 2 + nativity, specific origin group	0.010	1.10	0.015	1.12
4	Model 3 + poverty, urban/rural, 287g, ethnic density	0.011	1.10	0.015	1.12
5	Model 4 + poverty, urban/rural, 287g, ethnic density, year	0.011	1.11	0.013	1.11
6	Model 5 + 1-year lag ICI	0.012	1.11	0.012	1.11
7	Model 6 + 1-year lag ICI*nativity interaction	0.012	1.10	0.012	1.11

ICI = Immigration climate Index, MOR: Median Odds Ratio, 287g = 287(g) agreement in place between one or more police jurisdiction in the county and federal Immigration Customs Enforcement

Table 3. Estimated effect on VPTB risk of living in a state with a more restrictive immigration climate (lowest quintile of ICI) to living in a state with a less restrictive immigration climate (referent), as measured by the one-year lagged Immigration Climate Index, US-born and foreign-born Hispanic mothers in the United States, 2005-2016

	All Hispanic Mothers	**US-born Hispanic Mothers**	**Foreign-born Hispanic Mothers**
	N = 10,683,234	**N = 4,735,645**	**N = 5,947,589**
	aOR (95% CI)	**aRD per 1000 live births (95% CI)**	**aRD per 1000 live births (95% CI)**
ICI 1 v. 5	1.07 (1.04 - 1.1)	0.96 (0.49 - 1.44)	0.81 (0.35 - 1.27)
ICI 1 v. 4	1.07 (1.04 - 1.11)	0.44 (-0.13 – 1.00)	1.25 (0.71 - 1.79)
ICI 1 v. 3	1.06 (1.03 - 1.1)	0.28 (-0.33 - 0.89)	1.2 (0.65 - 1.76)
ICI 1 v. 2	1.03 (1 - 1.05)	0.29 (-0.15 - 0.72)	0.53 (0.13 - 0.92)

*All odds ratios and risk differences adjusted for maternal age, relationship status, nativity, specific Hispanic origin, education, county level poverty, ethnic density, rurality and participation in a 287(g) agreement, and state level proportion of undocumented residents out of total foreign-born

Table 4. Sensitivity analyses: Estimated effect on VPTB of living in a state with a more restrictive immigration climate to living in a state with a less restrictive immigration climate, as measured by the Immigration Climate Index (ICI), US-born and foreign-born Hispanic mothers in the United States, 2005-2016

	All Hispanic Mothers aOR* (95% CI)	**US-born Hispanic Mothers aRD* per 1000 live births (95% CI)**	**Foreign-born Hispanic Mothers aRD* per 1000 live births (95% CI)**
Varying the lag-time for ICI, Hispanic mothers			
2-year lagged ICI 1 v. 5	1.06 (1.03 - 1.09)	0.91 (0.43 - 1.4)	0.49 (0.01 - 0.96)
no-lag ICI 1 v. 5	1.07 (1.04 - 1.11)	0.96 (0.46 - 1.46)	0.82 (0.34 - 1.31)

*Adjusted for maternal age, relationship status, nativity, specific Hispanic origin, education, county level poverty, ethnic density, rurality and participation in a 287(g) agreement, and state level proportion of undocumented residents out of total foreign-born

Table 5. Estimated effects on VPTB of stress-promoting and stress-reducing factors, nested Generalized Linear Mixed Models with random effects for state and county, births to Hispanic women in the United States, 2005-2016

	aRD* per 1000 live births (95% CI)	**aOR* (95% CI)**
Social Support Indicators		
Relationship Status		
Married	-8.18 (-8.47 – -7.89)	0.60 (0.59 – 0.6)
Unmarried with father's information	-5.17 (-5.46 – -4.88)	0.76 (0.75 – 0.77)
Unmarried without father's information (referent)		
Percent Hispanic (County) (Highest Quartile v. Lowest Quartile)	-0.33 (-0.74 – 0.08)	0.98 (0.95 –1.01)
Stress Indicators		
287g yes/no (County)	-0.02 (-0.33 – 0.30)	0.99 (0.97 –1.02)
Percent below FPL (County) (Highest Quartile v. Lowest Quartile)	1.05 (0.62 – 1.49)	1.08 (1.04 –1.11)
Est. ratio of undocumented to all foreign-born residents (State) (Highest Quartile v. Lowest Quartile)	-0.04 (-0.61 – 0.54)	1.00 (0.96 –1.04)
US-born v. Foreign-born	1.36 (1.2 – 1.52)	1.11 (1.09 –1.12)

*Adjusted for maternal age, relationship status, nativity, specific Hispanic origin, education, county level poverty, ethnic density, rurality and participation in a 287(g) agreement, and state level proportion of undocumented residents out of total foreign-born

Figure 1

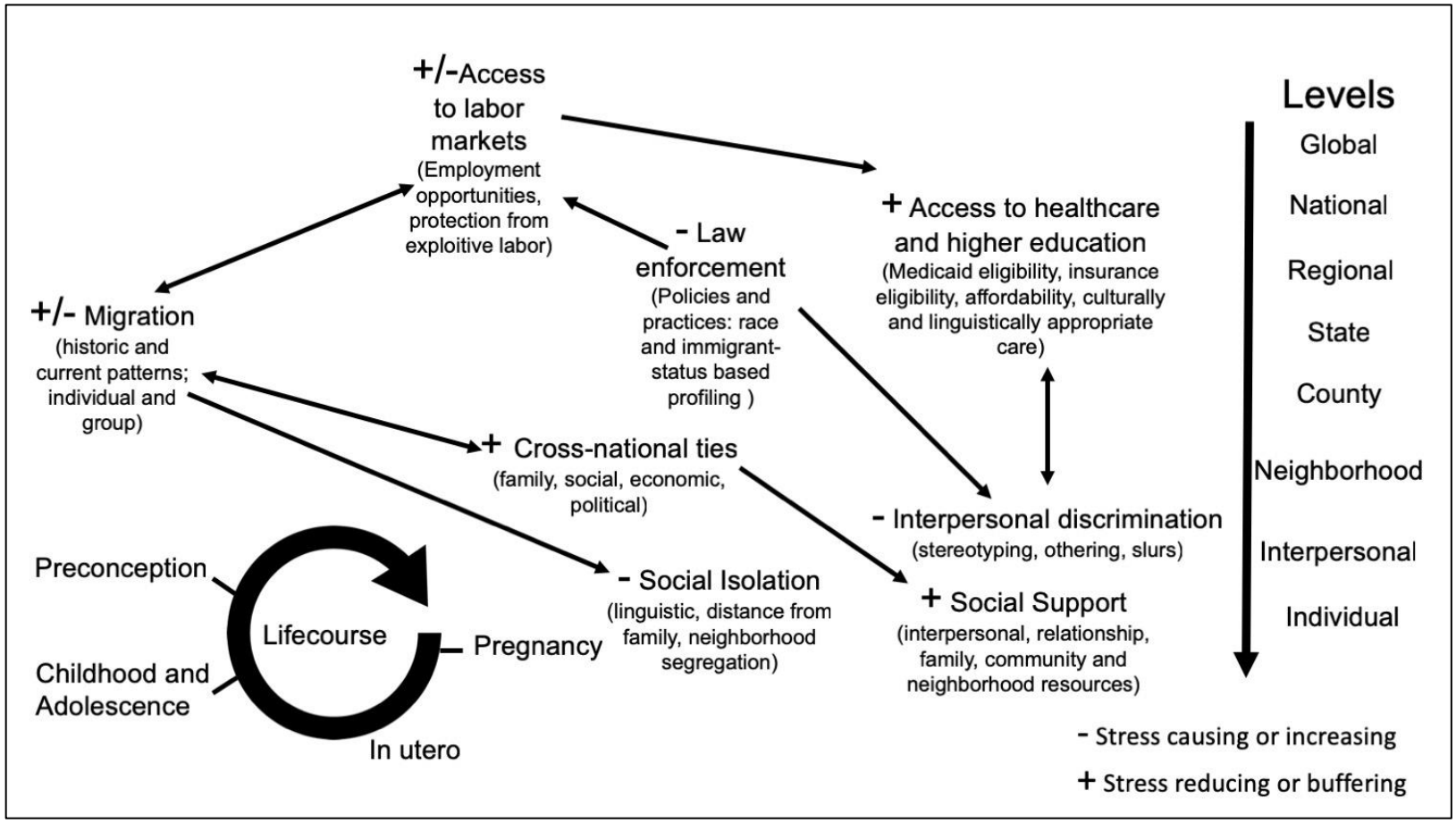

+/-Access to labor markets
(Employment opportunities, protection from exploitive labor)
+ Access to healthcare and higher education
(Medicaid eligibility, insurance eligibility, affordability, culturally and linguistically appropriate care)
- Law enforcement
(Policies and practices: race and immigrant-status based profiling)
+/- Migration
(historic and current patterns; individual and group)
+ Cross-national ties
(family, social, economic, political)
- Interpersonal discrimination
(stereotyping, othering, slurs)
- Social Isolation
(linguistic, distance from family, neighborhood segregation)
+ Social Support
(interpersonal, relationship, family, community and neighborhood resources)
Preconception
Lifecourse
Pregnancy
Childhood and Adolescence
In utero
Levels
Global
National
Regional
State
County
Neighborhood
Interpersonal
Individual
- Stress causing or increasing
+ Stress reducing or buffering

Figure 2

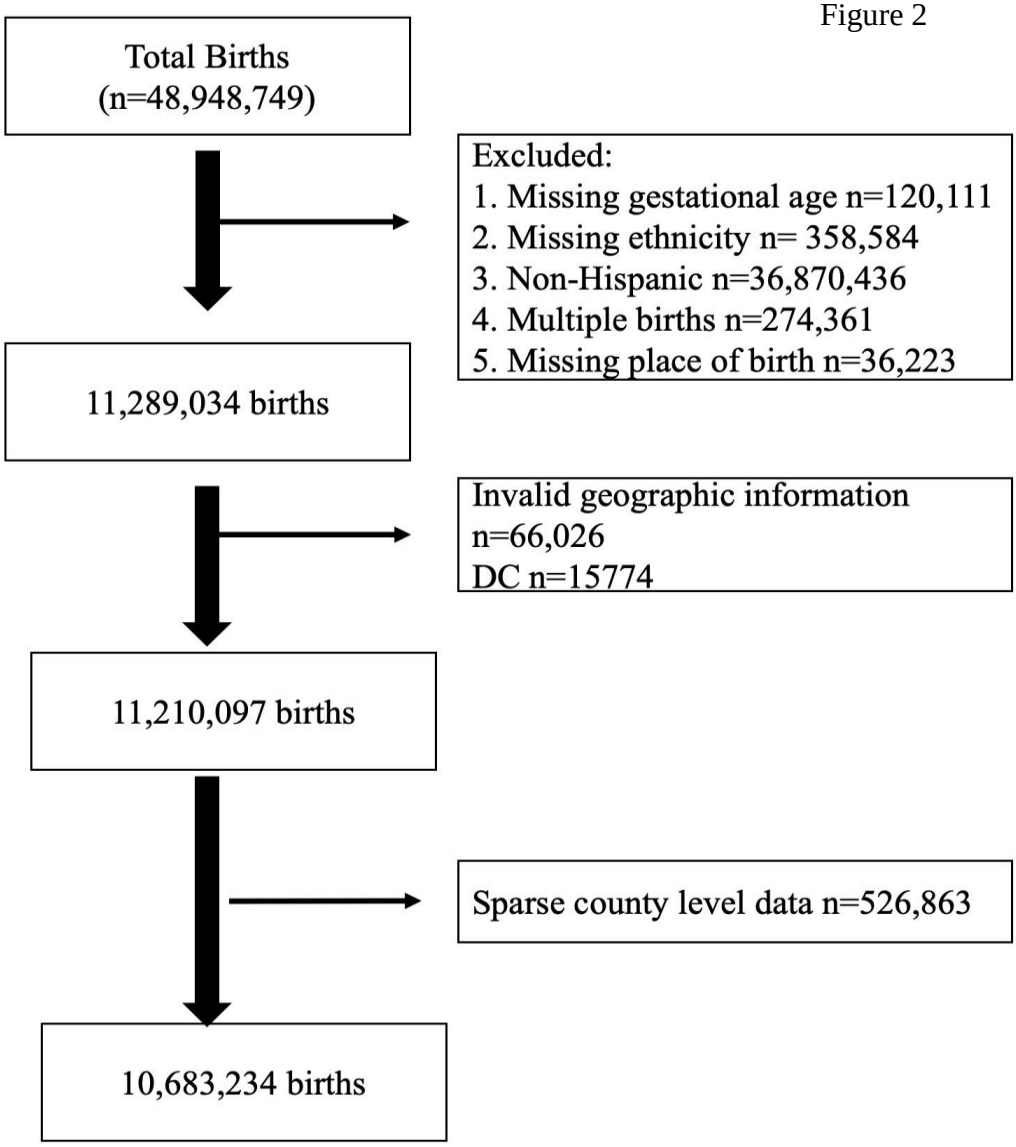

Total Births
(n=48,948,749)
Excluded:
1. Missing gestational age n=120,111
2. Missing ethnicity n= 358,584
3. Non-Hispanic n=36,870,436
4. Multiple births n=274,361
5. Missing place of birth n=36,223
11,289,034 births
Invalid geographic information
n=66,026
DC n=15774
11,210,097 births
Sparse county level data n=526,863
10,683,234 births

Figure 3

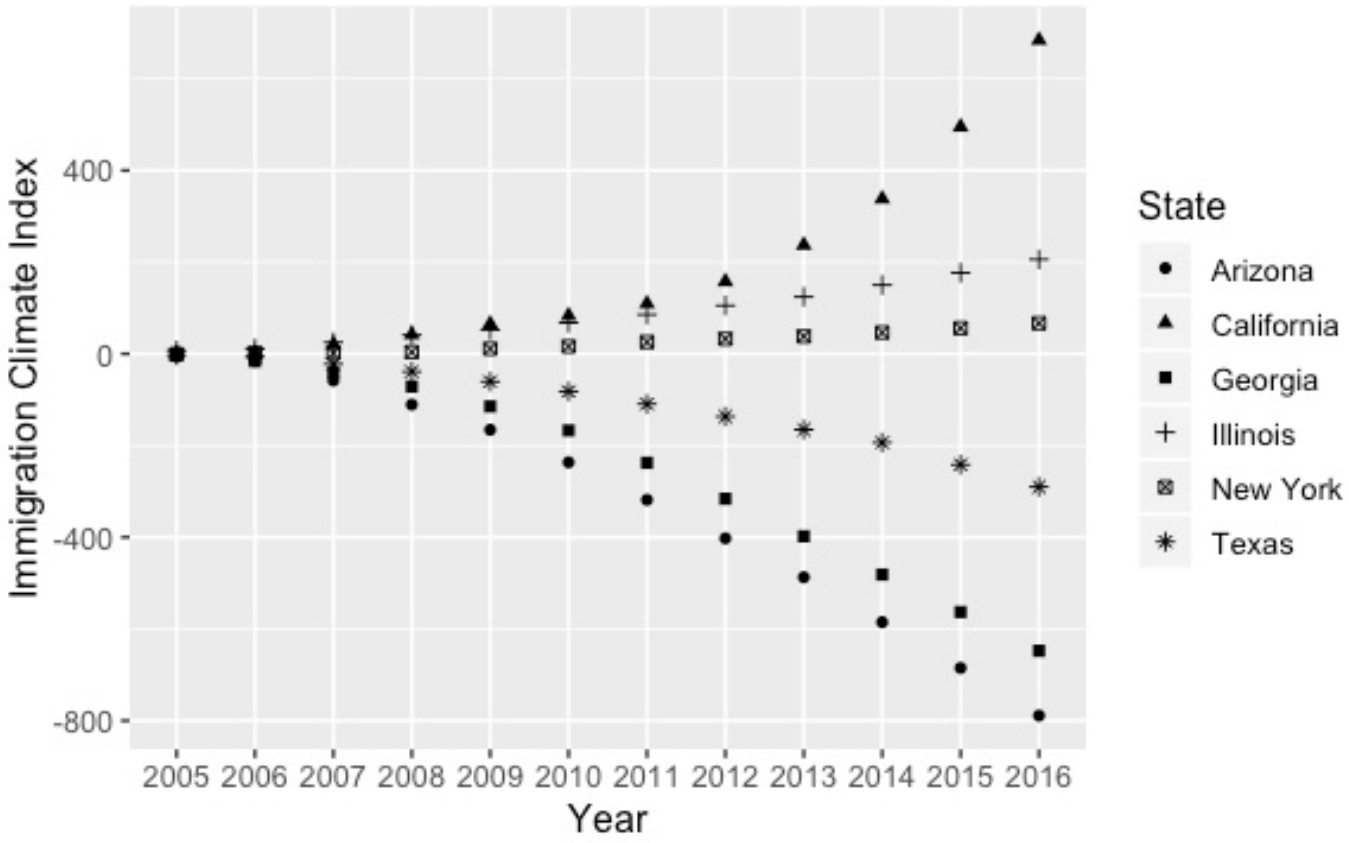
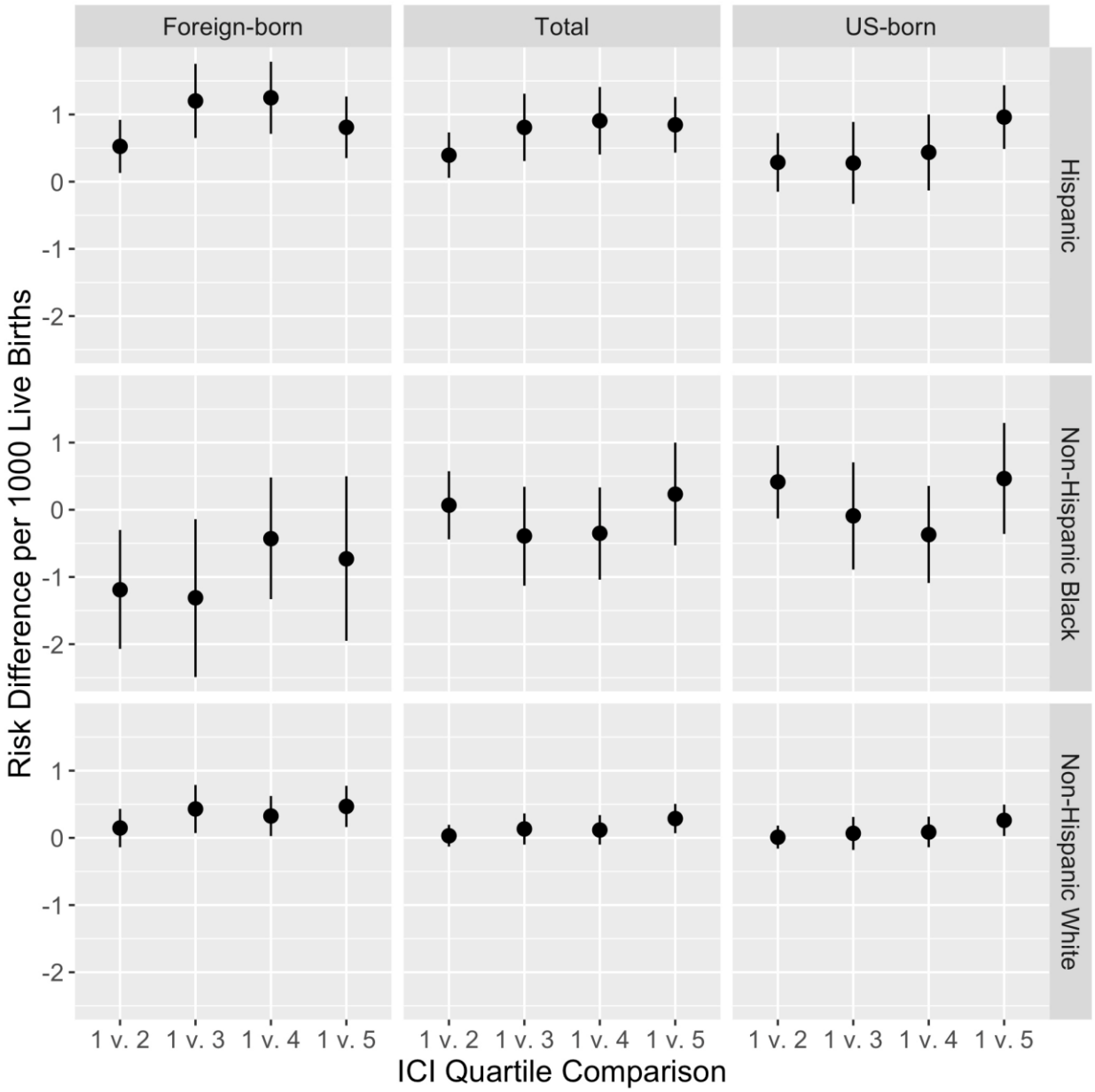

Immigration Climate Index
400
0
-400
-800
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Year
State
Arizona
California
Georgia
Illinois
New York
Texas

Figure 4



*Risk differences adjusted for maternal age, education, parity, county level poverty, percent Hispanic and participation in a 287(g) agreement and state level proportion of undocumented residents out of total foreign-born. Models for Hispanic mothers also adjusted for specific maternal origin group.