DRAFT: PLEASE DO NOT CITE WITHOUT AUTHOR PERMISSION

Social Inequality in Early twentieth-Century Puerto Rico: Population as a Mediator

Katherine J. Curtis White1
Center for Demography and Ecology
University of Wisconsin-Madison

March 2006

Word Count: 6,810

ABSTRACT

This study investigates the relationship between economic transitions, population responses, and resultant changes in the stratification system in early twentieth-century Puerto Rico. Multilevel regression techniques are used to estimate the relationship between economic production and social inequality within geographically-defined areas, and to test the hypothesis that the association between economic production the accompanying within-area social inequality was positively conditioned by population. Early twentieth-century Puerto Rico offers a compelling case for study since this period marks momentous shifts in political governance and economic interests with resultant changes in land use, population distribution, and social inequality. Social inequality is measured as individual literacy. Historical PUMS and aggregate census data are used to examine the influence of individual and ecological factors on literacy. Results indicate that natives and non-white residents had a lower probability of literacy. This relationship was especially pronounced for residents of high sugar-producing municipios and greater inequality was estimated among residents living in high populated municipios. The influence of ancestry versus nativity is also examined and study results show that having U.S. or Spanish ancestry may be more meaningful for inequality than nativity.

---

1 This work was supported by Research Grant F32 HD052345-01 from the National Institute for Child Health and Human Development, National Institutes of Health. Technical support was given by Bill Buckingham at the Applied Population Laboratory through the University of Wisconsin Center for Demography and Ecology GIA Core.

INTRODUCTION

Puerto Rico provides a persuasive case for the study of economic, demographic, and stratification transitions. The island was a Spanish colony for nearly four hundred years until possession was transferred to the U.S. in 1898 as a result of the Spanish-American War. This political transfer created fundamental shifts in the relationship between the population, the land, and the state, and had significant demographic and social consequences. Under U.S. control, Puerto Rico's economic infrastructure was entirely revamped with substantial effects on the system of land use, the regional distribution of the population, and the social class structure (Dietz 1986).

This fertile island remained sparsely cultivated and was populated by only a few thousand colonials, a majority of whom were African slaves, until the late seventeenth century since its primary function was a strategic colony for the expansion of the Spanish empire in the Americas. During the eighteenth century, however, increased economic activity in the French and English "sugar islands" motivated the Spanish to develop policies to expand Puerto Rico's commercial production of sugar, coffee, and tobacco, and to increase the supply of African slaves (Scarano 1984). The second half of the eighteenth century found Puerto Rico filling two roles; one function concerned military strategic interests and the other pertained to economic competition. Economic changes were accompanied by population expansion. Between 1765 and 1800, the island's population more than tripled, from just fewer than 45,000 to more than 155,000 residents (Scarano and White 2005). The level of economic expansion and population growth, however, was not evenly distributed across the island. The details of production (crop and intensity) and population (socio-racial composition) corresponded with one another, and varied in spatial distribution. This process produced an uneven social landscape that had profound implications that were immediate and lasted into the nineteenth and twentieth centuries.

In addition to slave status, Puerto Rico's population was bifurcated along additional socio-racial lines that gave rise to a sizeable peasant class called *jibaros*. The island elites, who consisted mainly of white non-natives, forced under penalty by law the otherwise free peasants to labor in the export sector on the elite-owned *haciendas*. The ecology of the island was, and remains, a rugged mountainous interior, agreeable climate, and rich soils. This environment and the history of easy access to land, mainly through squatting, permitted the *jibaros* to engage in subsistence farming and to strengthen as a peasant group throughout the nineteenth century, especially in its population size. Although the percentage of the island's land under export cultivation increased throughout the 1800s, the beginning of the twentieth century saw the majority of the land undeveloped and the population principally rural and engaged in subsistence farming, with seasonal employment through the haciendas.

This would all change with the U.S. invasion. Rapid expansion of sugar production along the island's coasts ensued and accelerated the proletarianization of Puerto Rico's native population. Commercial sugar production required substantial acreage as well as a large labor force. Land devoted formerly to subsistence farming by the *jibaros* was plowed for the production of export-oriented crops, mainly sugar. Indeed, the total value of exports more than tripled in the first ten years of U.S. occupation; the value increased from 8.6 million in 1901, to 30.4 million in 1909 (Department of Commerce Bureau of the Census 1913). The *jibaros* turned to wage labor as they lost their land that was their means of subsistence. Puerto Rico had become "a community of agricultural laborers" (Diffie and Diffie 1931), that found employment largely in sugar and tobacco as coffee cultivation diminished. Rapid shifts in Puerto Rico's population distribution accompanied and corresponded with the shift in crop production and marked a strong relationship between twentieth-century economic transitions and population processes; the interior coffee region declined while the coastal sugar plains grew.

U.S. capital revamped Puerto Rico's sugar industry rapidly, and in a way that was

consistent with the goals of nineteenth-century sugar producers. The earlier producers, however, had too little too late. A centralized system of sugar production emerged in the 1870s but did not come to full force until the U.S. occupation. The system, engineered by British colonizers, was designed to more efficiently "exploit colonial areas" (Mintz 1956:337). The intention was to centralize the production and processing of the sugar cane through a highly structured, and stratified, system of operation. Mintz offers the following, heated description of the U.S. land-and-factory combines, or factory centrales:

> They meant to create a flourishing sugar industry, and so they did. Where the land was dry, they watered it; where it was infertile, they fertilized it; where it was unused, they threw it into use; where it was used for other crops, they turned it to sugar cane; where it was owned and saleable, they bought it; where it could not be bought, they rented it. And this entire conversion process was clearly seen in terms of long-term investment. The new system dug itself in. (1956:338)

The centralized system gave rise to a laboring class and a managing hierarchy; a class of farm laborers who worked for wages, a smaller class of higher-status operators, and an even smaller class of even higher-status owners. This system and the corresponding social changes were unique to the sugar industry. U.S. interests and finances were concentrated largely on the sugar industry to the neglect of the other "after-dinner crops," and to the economic and social benefit of a select few of the Puerto Rican population.

Study Objective

The primary focus of this study is to examine the emerging distribution of inequality between racial and nativity groups, according to municipio characteristics, that accompanied the U.S.-led restructuring of the Puerto Rican economy and, in consequence, society. In general terms, I ask: How does population mediate or alter the nature of the influence of the economic change on inequality? The methodological strategy permits the explicit consideration of

temporal and spatial dynamics by testing for temporal variation and the influence of muncipio attributes.

It has been a tenet of scholarly literature that the structures of social and economic life within the American tropics were fundamentally determined by the ecology associated with the "after-dinner crops", especially those dominant in Puerto Rico: sugar, coffee, and tobacco (Wagley 1960; Steward et al. 1956). The extent to which this proposition, and the accompanying hypothesis concerning similarities and differences of plantation economies and the populations shaped by them, is viable has heretofore not been statistically and systematically tested. Review of Puerto Rico's economic and population history suggests that the process of societal development is influenced largely by ecology—the mountainous regions did not lend to sugar production and, therefore, did not invite larger populations that accompanied industry expansion—and prompts an analysis that considers attributes of the ecological level. Previous research depicts a process of uneven development according to shifts in crop production that was prompted by a change in economic focus associated with the transfer of political rule. This characterization motivates an analysis of the socioeconomic consequences of the shift.

Using historical census data, I address how population mediates the influence of the economic change on inequality in early twentieth-century Puerto Rico. The study question concerns the nature of the correlation between population and inequality, and is examined through multilevel modeling techniques that incorporate interactive relationships between individuals and their environment. This approach embeds individuals within the environment and, thus, permits the investigation of how social inequality emerges within areas and according to ecological attributes across time. Analysis of multilevel data allows me to properly assess the condition of inequality within ecological units, while considering the organizational implications of a regionally-distributed economic industry.

There are three hypotheses central to the study. First, the distribution of power shifted from Spain to the U.S., although the native and non-white population continued to be at a status-disadvantage. This argument motivates an analysis of the relationship between individual literacy and nativity and race. Second, the uneven development and land use that followed the U.S.-led economic transition may have had different implications for individual literacy. This line of reason motivates a test for the influence of ecological factors on literacy. Finally, the hierarchy of the sugar centrales might modify the influence of nativity and race on literacy, and the larger population size accompanying the fast-growing sugar regions might modify further the relationship between the environment and social organization. This argument motivates a test for the conditioning influence of population size on the relationship between sugar production and nativity-race in its influence on literacy.

DATA, MEASURES & METHODS

Data

Use of both aggregate and individual-level data is necessary for a thorough exploration of how population mediates the relationship between economic production and inequality. Aggregate data are from the 1910 and 1920 published census volumes and individual data are available through newly created 1910 and 1920 Puerto Rican PUMS files (Palloni et al. 2000) that will soon be available through IPUMS and ICPSR in differing formats (for more information see Velyvis et al. 2006). The data are pooled and analyzed simultaneously, rather than separately by year. Temporal dynamics are further elaborated in the discussion of the methodological approach. The PUMS data are embedded within the aggregate data for the multilevel analysis of inequality within areas. The PUMS files are sample data rather than a complete population count and require the use of a weighting scheme (see Velyvis et al. 2006).2 Use of the individual data are not aggregated or intended to reflect the municipio

2 Bootstrapping techniques to obtain more prudent inference estimates are planned for the next

population. Rather, the individual characteristics are embedded with the municipio characteristics to analyze the correlates of socioeconomic inequality within area, where the area is treated as area attributes instead of a specific geographical unit.

Measures

Indicators of social inequality are incorporated at both levels of the analysis: the proportion literate at the ecological-level, and literacy (literate versus illiterate) at the individual-level. Literacy indicates the ability to both read and write, although not necessarily in English. Individual-level literacy is treated as the outcome variable. Occupation or industry and income are common indicators of socioeconomic status and the base from which measures of inequality are derived. While occupation and industry are available in the micro-data files, income data are not and they are not available at the aggregate level. The treatment of literacy as an indicator of socioeconomic status in this historical context is both appropriate and defensible since it aptly taps an attribute on which the society was stratified, and on which other indicators of socioeconomic status are related (e.g., occupation).

The distribution of literacy for the pooled data, and separately by year, is reported in Table 1. Approximately ten years after U.S. occupation, a third of the Puerto Rican population could both read and write. Twenty years after U.S. governance, around 40% of Puerto Rican residents were literate. By comparison, 92% of the mainland U.S. population was literate in 1910, and 94% were literate in 1920 (Carter et al. 2006:2-468). A list of municipios ranked by literacy proportions, as well as the number of PUMS respondents within each municipio is reported in the appended Table 1A. San Juan was the top-ranking municipio with nearly 70% literate residents, and was the most urban municipio on the island. Mayguez was also among the top-ranked municipios and, like San Juan, was a highly-populated municipio. In contrast, the second-ranking municipio of Culebra was a low-density, smaller island off of the eastern

---

phase of analysis.

coast; 63% of its 106 pooled-residents were literate.

[Table 1 About Here]

The central individual-level predictors of literacy are nativity and race. As discussed earlier, stratification in early twentieth-century Puerto Rican society is expected to fall along nativity and racial lines. Puerto Rico has a history in the slave trade linked with the sugar industry (Scarano 1984), which has had important implications for the island's racial dynamics. Slavery was abolished in 1873 although labor agreements and opportunities did not promote equality. Ex-slaves, according to Mintz (1956:337), were new members of the agregados ("white slaves"). Despite Puerto Rico's history of racial diversity and "mixing" through intermarriage, race in the early twentieth-century still signified a rank in the social structure; the higher the social status, the whiter one became either because of a lighter complexion, or because of a racial status newly assigned when a higher status was achieved. Census enumeration practices at this time required the enumerator to assign the respondent's race and not the respondent, herself. It is likely that the reported race is, in part, a reflection of the respective respondent's status in the community because the enumerators were members of the community and knowledgeable of its dynamics.3

In addition to race, the island's colonial status has had important consequences for class differences between native and non-native Puerto Ricans. Several policies promoting the in-migration of capital-rich émigrés were adopted during Spanish Rule. For example, in 1815 the Cédula de Gracias was a program that enticed non-native Catholics by offering land from the royal domain (in amounts that were proportional to the number slaves owned) (Mintz 1956:335). The program provided free importation of machinery, removed taxes on slaves and agricultural implements, and established tariff-free commerce with Spain. Under U.S. rule, similar policies promoted the importation of mainly capital, but also capital-rich migrants from mainland U.S. In

Puerto Rico the greatest status, or economic and political power, tended to be awarded to residents who were white and of Spanish origin, and of U.S. origin after 1898. In this study, whites and non-natives are anticipated to have the highest odds of literacy.

Nativity reflects whether the individual was born in Puerto Rico; it essentially indicates whether the respondent is a migrant to Puerto Rico although there is no information on the timing of the migration. Data on respondent birthplace is used in combination with information on parent birthplace to construct ancestry variables that are analyzed to gain insight on the role of nativity in stratifying Puerto Rican society. Three racial categories are constructed to reflect whether the respondent is black, mulatto, or white/other. The "other" category is comprised of Chinese and Japanese individuals, although there are a negligible number of these individuals (0.0026% of the sample in 1910 and 0.0025% in 1920). The "other" race group is included in the analysis to maintain comparability with the municipio-level variables even though the inclusion is, ultimately, inconsequential.

The second key predictor of individual literacy is municipio economic production, measured as the proportion of crop-specific acreage of the total farm land for sugar, tobacco, coffee, and all other crops (combined). Sugar and tobacco production expanded immediately following the U.S. invasion given the high export value, whereas the production of coffee and subsistence crops diminished. The descriptive statistics show that the majority of the farmland was devoted to the production of other crops, or subsistence farming. Still, 9% of the island's farmland was devoted to sugar production for both years combined, increasing from 8% in 1910 to 11% in 1920. There is considerable variation in sugar production across the municipios, with some having more than 30% of its farm acres devoted to sugar production while others have no sugar acreage. As depicted in Figure 1, sugar production is limited to the coastal plains. Sugar acreage is anticipated to condition the relationship between nativity and literacy, and race and

---

3 More on the topic of race in Puerto Rico during this period, and using the PUMS data, can be

literacy, in the following manner: being native and non-white will have a more deleterious influence on literacy for residents of sugar-producing municipios.

[Figure 1 About Here]

The third central independent variable is municipio population and is anticipated to further condition the relationship between nativity-race, sugar acreage and literacy; being native and non-white will have a more deleterious influence on literacy for residents of sugar-producing municipios, especially for residents of highly populated municipios. Even greater inequality is anticipated among residents of larger municipios. The total population reported in published census volumes for 1910 and 1920 has been transformed to reflect the total population per 10,000 since the HLM software is sensitive to different scales among the variables included in the analysis, and other ecological-level variables are measured in proportions. The mean population for the pooled sample is 17,778 and ranges from 839 to 71,443, with Culebra having the lowest population and San Juan and Ponce having the largest.

Several covariates anticipated to have a relationship with literacy are also included in the analysis. Additional ecological covariates are indicators of the demographic structure and include the proportion of the municipio population that was black, mulatto, and white, as well as nativity categories that indicate the proportion born in Puerto Rico and the proportion born in Spain. Aggregate-level data on the proportion born in the U.S. was not reported in the published census volumes. Information on "other" races was reported in the volumes, but comprised such a small proportion that it was, in application, combined with the proportion white for the analysis by omitting it from the regression analysis (i.e., the "other" race category had a mean of 0.000019 in 1910, and 0.000018 in 1920). The reference category, in effect, is both white and "other" race groups, with "other" race comprising a negligible proportion. At this point in Puerto Rican history, "other" races largely referred to Chinese and Japanese.

---

found in an unpublished manuscript by Loveman and Muniz (2006).

Other covariates included in the analysis are indicators of individual demographic and economic characteristics: gender, age, family status, household composition, and industry. Male is coded “1” if the respondent is male and “0” if she is female. Gender is included in the analysis to account for any gender dynamics that may have affected the likelihood of literacy; in general, males are anticipated to have higher literacy given gender stratification that benefited male status and employment. Age is treated continuously and ranges from 10 to over 100, with a mean of 31 years-old. The sample is restricted to respondents aged 10 and older to maintain consistency with the aggregate-level information on literacy. Data on municipio literacy pertains to the sub-population aged 10 and older in both 1910 and 1920. Age is included in the analysis to control for the potential higher probability of literacy among the younger, school-aged individuals relative to older Puerto Ricans who may not have had the same exposure to education as twentieth-century youth.

The remaining demographic covariates address family status and household composition. Family status captures respondent marital status and consists of the following categories: married, consensual union, divorced or widowed, and single. Single serves as the reference category throughout the study. Household composition reflects whether it is a family household and its complexity. Simple family households are comprised of couples, single-parents, and nuclear families. All household members are related to one another. Complex family households include extended families although they do not require a conjugal union. For example, a complex household may have a grandfather as the household head who lives with his daughter, his son and the son’s two children. Non-family households consist of individuals and households with no related members. The household categories are adapted from the seven-category typology used in De Vos’s (1995) research on Latin American households. Simple family households are used as the reference category in the analysis. Family status and household composition are not given theoretical attention in the current study but are included

to account for any influence on literacy that may otherwise be attributed to the factors of central focus, namely nativity, race, sugar production, and population size.

Respondent industry measures whether the individual is engaged in crop production and, if so, which crop. Although the range of potential categories includes all options listed in the 1950 industry classification code and is numerous, I have reduced the industry roster to four farm categories and one non-farm category. Information on the farm categories is unique to the Puerto Rican PUMS data and is included because of its relevance to the Puerto Rican case. The variables reflect whether the individual is engaged in the sugar, tobacco, coffee, or other crop industry. The other crop category likely implies subsistence farming. The non-farming variable captures all other individuals not engaged in the farming industry. This was by far the largest industry category during this period, with 59% of the respondents. Among the crop producers, sugar farmers and subsistence farmers comprised 15% and 16% of the total sample, correspondingly.

Unfortunately, data on industry involvement was not reported for all sample members and has important consequences for the 1920 sample. In 1910, if an individual was in school and not working, then the occupation was coded “in school” and the industry was generally “public” or “private.” In 1920, the occupation for anyone who was not gainfully employed was noted as “none” and the industry was left blank. This blank entry results in the exclusion of these individuals since there is no industry information. Of the sample included in this analysis, 9,011 (8,946 in 1910 and 65 in 1920) are knowingly in school. The school-attending sub-population is not excluded from the analysis since this would carry important implications for the dependent variable, literacy. Among the in-school respondents, 79% are literate and they range in age from 10 to 25 years-old with a mean of 12 years-old and a standard deviation of 2 years. Including age in the analysis is intended to address the stronger likelihood that the younger population had a greater probability of being literate relative to the older population.

Methods

Generalized hierarchical linear models (GHLM) are used to model the likelihood of individual literacy (see Bryk and Raudenbush 1992; Luke 2004; and Raudenbush and Bryk 2002) and are estimated through HLM software (Raudenbush et al. 2005). Two-levels are modeled to account for the dependence among the individual-level attributes within municipio, across time. The fixed effects of the individual-level attributes are allowed to vary, and are modeled as random effects, according to the ecological context, and can be represented by the following equations:

Level 1 (Individual & Time): $Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + ... + r_{ij}$

Level 2 (Ecological/Space): $\beta_{0j} = \gamma_{00} + \gamma_{01} W_j + ... + u_{0j}$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} W_j + ... + u_{1j}$$

For level 1, Y_{ij} is the outcome variable, measured as literacy, and is modeled as a logit function given its binary format; β_{0j} is the individual-level intercept; $\beta_{1j} X_{ij}$ and the following $\beta_{kj} X_{ij}$'s are the individual-level predictors, such as nativity and race as well as year (1910 and 1920); and r_{ij} is the error term.

For level 2, β_{0j} is the level-1 intercept in level-2 observation *j*; γ_{00} is the mean value of the level-1 dependent variable, literacy, when controlling for the level-2 predictor W_j, for example, sugar production; γ_{01} is the effect, or the slope, of the level-2 predictor W_j; and u_{0j} is the error or unmodeled variability for unit *j*. For the second part of level 2, β_{1j} is the level-1 slope in level-2 unit *j*; γ_{10} is the mean value of the level-1 slope when controlling for the level-2 predictor W_j; γ_{11} is the effect of the level-2 predictor W_j; and u_{1j} is the error for unit *j*. In sum, the level-2 component of the model indicates how each of the level-1 parameters, including

intercepts and slopes, is a function of the level-2 predictors and variability (Luke 2004:10).

The individual PUMS data are pooled for 1910 and 1920 but are not treated as longitudinal data, per se, because they are independent samples derived from two sets of census manuscripts. The data are, therefore, not repeated observations of the same respondents. Consequently, the statistical dependence introduced into the individual-level data is at the ecological level (level 2) since respondents are nested within municipios. Indeed, the estimated inter-class correlation (ICC) (results available from the author on request) indicates that municipios account for 19% of the variability in literacy among early twentieth-century Puerto Ricans. The ICC suggests that multilevel modeling might be a useful analytical approach for these data.

The municipio census data is also pooled across the two decades. The dependence introduced at level 2, however, does not bias the estimates for the individual-level outcome, literacy. Instead, this dependence is analogous to correlation between independent variables in the single- and multi-level approach. Multicollinearity diagnostics were used to identify potential problematic correlations among the predictors at both levels 1 and 2, and none were found.

The incorporation of the level-2 factors is also theoretically motivated. A cross-level interaction is anticipated between the ecological factors and individual attributes on literacy; nativity and race differences in literacy are expected to be greater among individuals within sugar producing municipios, especially those residing in higher populated municipios. Space, or the ecological unit, is expected to influence individual intercepts and slopes. Time is also expected to influence individual and space intercepts and slopes. The anticipated relationships have the following model implications:

Level 1 contains the individual factors pooled across time periods as well as binary indicators of time (1910 and 1920, coded as “10” and “20”), and are treated as fixed effects. Tests for non-linear relationships between time and key individual attributes (e.g., nativity and

race) are conducted by estimating interaction terms between time and individual characteristics. This approach produces two results. First, it tests whether there are temporal effects among the individual-level relationships. Second, model results also indicate whether there is significant variation in the relationship that may be explained by factors at the ecological level or, otherwise stated, whether there are spatial effects on the (temporally-variant) individual-level relationships.

Level 2 contains the ecological attributes pooled across time periods and are treated as random effects. Central analytical focus is on the cross-level associations, especially the relationship between sugar production and population size (the ecological factors) and nativity and race (the individual, potentially time-varying factors). Including time at the level 1 model addresses two needs associated with the spatio-temporal context in which the social inequality emerges: (1) it tests for temporal variation in the association between individual-level factors and literacy; and (2) it tests for spatial (attribute) variation in the temporally-varying individual-level relationships.

FINDINGS

Tests for time-varying associations between key individual-level predictors and literacy were conducted, and are reported in Table 2.4 Results indicate that literacy for the average Puerto Rican improved between 1910 and 1920, from an estimated 25% probability of being literate to 39% (see Model 1). There is, however, no evidence of a dramatic change in the influence of nativity or race across time. There is weak statistical evidence of a time-varying association between literacy and being mulatto in Model 4 (β=0.01, p-value=<0.1), which suggests that the negative influence of being mulatto was less detrimental in 1920 than in 1910.

---

4 The variance component of the error reported at the bottom of Tables 2 through 4, sometimes referred to as the dispersion index, indicates a good fit between the observed errors and the theorized binomial distribution. A 1.00 indicates a perfect fit, whereas values less than 1.00 indicate under-dispersion and values greater than 1.00 are indicative of over-dispersion (see Luke 2004:57).

Accounting for time-variation in the effect of being mulatto yields an estimated 18% probability of being literate (versus 19%, without accounting for the conditioning influence of time) in 1910, and a 31% probability (versus 30%) in 1920. Evidence of any temporal variation, in the form of a direct association with literacy, is attenuated when the influence of the municipio-level factors is considered (see Table 3). The temporal variation appears, in large part, to be explained by dynamics at the municipio level; the spatial attributes attenuate the influence of time on literacy.

[Table 2 About Here]

[Table 3 About Here]

Nativity & Race

Several other individual factors, as well as municipio factors, are associated with literacy and reported in Model 1 of Table 3, though only those of central theoretical focus are discussed. Previous research has suggested that Puerto Rican society was largely stratified according to nativity and race. Results from the multilevel analysis that incorporates individual and municipio correlates of literacy (Model 1 in Table 3) support this claim. As anticipated, being black or mulatto significantly decreased the odds of being literate relative to being white (about 45%). In addition, nativity was negatively associated with literacy; native born Puerto Ricans had an estimated 31% probability of literacy versus an 85% probability for foreign-born residents. Native Puerto Ricans were at a 54 percentage-point disadvantage.

Sugar Production

Key to the theoretical subject at hand, results show that whether one was engaged in crop production and the specific type of crop production was relevant for literacy. Individuals engaged in crop production had a lower odds of being literate compared to individuals employed in non-agricultural industries. This finding is not necessarily surprising. A unique contribution of the results, however, is an estimate of the influence for each of type of producer.

Figure 2 illustrates the differences in the impact of an individual's industry while

considering the additional influence of other individual and ecological factors. The figure displays the predicted probabilities of being literate according to farm-industry status, and is calculated by applying the mean values of all variables except farm-industry status to the logit coefficients reported in Model 1 of Table 3. The difference in the odds of literacy between non-farmers and farmers is striking. For sugar farmers, there was an estimated 32 percentage-point disadvantage. The magnitude of municipio crop production is illustrated in Figure 3, and demonstrates the difference in the individual-level influence compared to the municipio-level impact of crop production. In terms of individual effects, sugar farmers were at the bottom of the literacy ladder relative to all other farmers and non-farmers. Regarding municipio effects, residents of sugar-producing municipios had a lower odds of being literate than residents of tobacco- and coffee-producing municipios. 5 Residents of subsistence-farming (all other crops) municipios had the lowest probability of literacy. These results indicate that sugar farmers and residents of sugar-producing municipios had the lowest probability of literacy among Puerto Rico's three top crops—sugar, tobacco, and coffee. In contrast, tobacco farmers and residents of tobacco-producing municipios had the highest probability of literacy.

[Figure 2 About Here]

[Figure 3 About Here]

Cross-Level Interactions: Nativity, Race, Sugar & Population

Thus far, the analysis has addressed the extent to which individual and municipio factors influenced literacy. The analysis now turns to the potential cross-level interactions between nativity and race, sugar production, and population size to test the hypothesis that the association between economic production and within-area social inequality was <u>positively</u> conditioned by population; the greater the population, the greater the inequality. The relationship between literacy and nativity and race captures the within-area social inequality.

5 The statistical significance of the sugar acreage coefficient is attenuated by the municipio

This association is anticipated to have varied according to economic production, specifically sugar production. Moreover, this interactive relationship is expected to have been further conditioned by population size; differences in the probability of literacy between the various nativity/race-sugar production categories are expected to be magnified in higher-populated areas.

Tests for this complex relationship are reported in Models 2 through 4 in Table 3, with separate tests conducted for nativity and each race category. Results show strong statistical support for variation in the negative influence of nativity by sugar production, and further variation by population size, but weak evidence of variation in the negative influence of race. The remaining discussion focuses on nativity given the underwhelming evidence for variation in the influence of race. Figure 4 is reported to demonstrate concisely the implications of the three-way interaction with nativity. The estimated probability of literacy is reported by for native and non-natives with varying sugar acreage for the minimum and maximum population size, separately.

[Figure 4 About Here]

There are several implications of the results. First, the probability of literacy varied across sugar acreage, but only among residents within higher populated areas. There was virtually no difference in the probability of literacy among residents within lower populated areas. The extent of dispersion in literacy was 3 and 1 percentage-points across the sugar acreage categories for native and non-native residents of lower populated areas, respectively. By comparison, there was an estimated 54 and 83 percentage-point range among native and non-native residents of higher populated areas, correspondingly. Variation in literacy was greater among residents of higher populated municipios.

Second, sugar acreage was negatively associated with literacy, and was especially

---

proportion literate.

meaningful for residents of higher populated areas. For example, native residents of highly populated areas with an average amount of sugar acreage had an estimated 9% probability of literacy. In contrast, native residents within a similarly populated area but with a one-standard deviation decrease in sugar acreage had an estimated 26% probability. This was a 17 percentage-point advantage for natives living within highly populated, low sugar-acreage municipios. Comparable residents with a one-standard deviation increase in sugar acreage had an estimated 3% probability.

Third, the low sugar-acreage advantage was conditioned by nativity; non-native respondents had a higher estimated probability of literacy compared to native respondents. Non-native Puerto Ricans living within a highly populated municipio with average sugar acreage had an estimated 65% probability of literacy. Non-natives had a 56 percentage-point difference over native Puerto Ricans living within a municipio of comparable size and sugar acreage.

Fourth, the extent of within-group dispersion was greater among non-natives than natives, among residents living in higher populated areas. Being non-native and living within a high populated and low sugar-acreage municipio was advantageous for literacy in terms of overall probability, but this advantage was accompanied by a larger potential inequality in literacy among non-natives. Estimated probabilities for natives living within high populated municipios of varying sugar acreage ranged from 1% to 55%, a 54 percentage-point spectrum. For non-natives living within these municipio-types, estimated probabilities ranged from 13% to 96%, an 83 percentage-point difference. There was a nearly 30% difference in the native and non-native scales.

Nativity versus Ancestry

Combined, these results indicate that differences in the probability of literacy between the various nativity-sugar acreage categories were magnified in higher populated areas. Yet additional information about the organization of social inequality in early twentieth-century

Puerto Rico can be distilled from a more detailed analysis of nativity.

Nativity is measured as the birthplace of each individual. In essence, this measure isolates recent (first-generation) migrants to Puerto Rico. During the first two decades of the twentieth century, dominant in-migration presumably was among people of European, especially Spanish, and U.S. origin. The measure of nativity, however, does not permit the analysis of longer-term (second-generation) migrants to Puerto Rico and, therefore, fails to capture the influence of being the offspring of previous Spanish or U.S. migrants who tended to possess a higher social rank in Puerto Rican society. Information on the birthplace of respondents' mother and father is available in the PUMS data and makes possible an analysis of the influence of Spanish and U.S. ancestry.

Results from the analysis of both nativity and ancestry for all individuals with information on at least one parent are reported in Table 4.6 As anticipated, being of Spanish and U.S. decent was positively associated with literacy. But more important, the interactive relationship between nativity, sugar production and population size was no longer evidenced when considering the interactive relationships with ancestry. The implications of the higher-order associations are illustrated in Figure 5.

[Table 4 About Here]

[Figure 5 About Here]

Like Figure 4, the estimated probability of literacy is reported by sugar acreage separately for residents of municipios of maximum and minimum population size. But, unlike Figure 4, Figure 5 reports the estimated probabilities by nativity and ancestry group, rather than nativity only. Consistent with the analysis of nativity alone, the probability of literacy varied

6 Several iterations of analysis were conducted although not all results are reported. In addition to the analysis presented in Table 4, I also examined the influence of combined nativity-ancestry variables (i.e., native of Spanish descent; native of U.S. descent; non-native of Spanish descent; and non-native of U.S. descent). Results did not deviate from the more parsimonious analysis presented.

across sugar acreage, but only among residents within higher populated areas; and sugar acreage was negatively associated with literacy, and was especially meaningful for residents of higher populated areas.

Results of the ancestry analysis also demonstrate two notable differences. First, the low sugar-acreage advantage was less conditioned by nativity than by ancestry. This observation is more easily detected among residents of municipios with the minimum population size. There is little observed difference in the probability of literacy between native and non-native Puerto Ricans of Spanish or U.S. descent compared to the differences noted between natives and non-natives of other ancestry. For example, the non-native/Spanish residents of low populated municipios with low sugar acreage (-2 standard deviations) had a 16 percentage-point advantage over native/Spanish residents. Comparable residents of U.S. descent had an 8 percentage-point difference. In contrast, there was a 40 percentage-point disparity between non-natives and natives of other ancestry. The differences were comparable among residents of high populated, low sugar acreage municipios: an 8 percentage-point difference among Spanish ancestry; a 3 percentage-point difference among U.S. ancestry; and a 34 percentage-point difference within the other ancestry group.

Second, for residents of high populated municipios, the extent of within-group dispersion was greater among non-natives of other descent, whereas the reverse was true for residents of Spanish or U.S. descent. Being non-native, of Spanish or U.S. descent, and living within a high populated and low sugar-acreage municipio was advantageous for literacy. Yet this advantage was accompanied by a larger potential for inequality in literacy for individuals of other ancestry only. Estimated probabilities for natives of other ancestry living within high populated municipios of varying sugar acreage had a range of 51 percentage-points, compared to 77 percentage-points for non-natives. In contrast, estimated probabilities for natives of Spanish descent living within high populated municipios of varying sugar acreage had a range of 82

percentage-points, versus 52 percentage-points among non-natives. The corresponding differences for natives and non-natives of U.S. decent were 79 and 33 percentage-points. Greater inequality is observed among non-natives of other descent, and greater inequality is observed among natives of Spanish and U.S. ancestry.

The detailed analysis of ancestry reveals that the greater potential of inequality that accompanied the advantaged status of being non-native does not hold for recent migrants of Spanish and U.S. ancestry. These individuals had a lower scale of dispersion compared to their native-born counterparts. This finding indicates that being a recent, first generation migrant from Spanish or U.S. ancestry placed Puerto Rican residents at a significant advantage over other residents in terms of literacy and, ultimately, social status during the first two decades of U.S. occupation and economic restructuring.

Summary & Discussion

The multilevel analysis of literacy in early twentieth-century Puerto Rico reveals three significant findings. First, native and non-white residents were at a literacy-disadvantage relative to non-native and white residents. Second, ecological attributes interacted with individual-level characteristics. Specifically, the negative influence of nativity was more pronounced for residents of high-populated, sugar-producing municipios; and a greater dispersion in the probability of literacy according to sugar production was estimated for residents of high-populated municipios. The association between sugar production and within-area social inequality was positively conditioned by municipio population size. Finally, the analysis of ancestry yielded greater insight on the role of nativity. Non-native Spanish and U.S. descendants were at a particular advantage over other Puerto Ricans; this group had a higher probability of literacy and a lower degree of dispersion or inequality on average and especially when residing in high-populated municipios.

Study findings reveal that the U.S. occupation and the ensuing economic restructuring

had different implications for residents of Puerto Rico. The island's overall literacy rate was considerably lower than that of mainland U.S. during the same decades. But the summary statistic masks important variation, and correlates of the variation, among members of the population. And the unconditioned influence of nativity does not tap the nuanced repercussions of being a native in different types of municipios. Incorporating muncipio factors and examining the mediating influence of economic production and population size shows that development and its advantages were unevenly distributed across the island's residents, and that the unevenness fell according to ecological attributes.

The fortunes won through the sugar industry did not last throughout the remaining decades of the twentieth century. The industrial revolution reached Puerto Rico; the sugar industry virtually was wiped out and Puerto Rico became a focus of industrial manufacturing for the mainland U.S. Analysis of the implications of this second U.S.-led economic transition is worthwhile to gain additional insight on the broader relationship between economic restructuring, population responses, and social inequality. How did residents of the sugar-producing municipios fare? Was within-area inequality replaced by a larger between-region difference as the population redistributed to the economically expanding municipios? But prior to the island's industrialization, Puerto Rico served as a testing ground for many New Deal land reform programs. Some of the programs were held in common with mainland U.S., while others were more radical than mainlanders preferred. The consequences of modern land reform policies have garnered some scholarly attention, but more and renewed focus would be beneficial given the detailed data that are within reach.

LITERATURE CITED

Bryk, Anthony S. and Stephen W. Raudenbush. 1992. *Hierarchical Linear Models: Applications and Data Analysis Methods*. Newbury Park: Sage Publications.

Carter, Susan B., Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch,

and Gavin Wright. 2006. *Historical Statistics of the United States: Earliest Time to the Present.* Millennial Edition. Volume 2: Work and Welfare. New York: Cambridge University Press.

De Vos, Susan M. 1995. *Household Composition in Latin America*. New York: Plenum Press.

Department of Commerce Bureau of the Census. 1913. *Thirteenth Census of the United States Taken in the Year 1910: Statistics for Porto Rico*. Washington: Government Printing Office.

Diffie, Bailey and Justine Diffie. 1931. *Porto Rico: A Broken Pledge*. New York: Vanguard Press.

Dietz, James L. 1986. *Economic History of Puerto Rico: Institutional Change and Capitalist Development*. Princeton: Princeton University Press.

Loveman, Mara and Jeronimo Muniz. 2006. "How Puerto Rico Became White: An Analysis of Racial Statistics in the 1910 and 1920 Censuses" Unpublished Manuscript.

Luke, Douglas A. 2004. *Multilevel Modeling*. Thousand Oaks, CA: Sage.

Mintz, Sidney W. 1956. "Cañamelar: The Subculture of a Rural Sugar Plantation Proletariat." In Steward et al. *The People of Puerto Rico: A Study in Social Anthropology*. Urbana, IL: University of Illinois Press. Pp. 314-417.

Palloni, Alberto, Francisco Scarano, and Halliman Winsborough. 2000. "Public Use Samples of 1910 & 1920 Puerto Rican Censuses." Grant Application to the Department of Health and Human Services Public Health Service.

Raudenbush, Stephen W. and Anthony S. Bryk. 2002. *Hierarchical Linear Models: Applications and Data Analysis Methods*, 2nd Edition. Newbury Park: Sage Publications.

Raudenbush, Stephen W., Anthony S. Bryk, Yuk Fai Cheong, and Richard T. Congdon, Jr. 2005. HLM for Windows Version 6.02a. Lincolnwood: Scientific Software International.

Scarano, Francisco A. 1984. *Sugar and Slavery in Puerto Rico: The Plantation Economy of Ponce, 1800-1850*. Madison, WI: University of Wisconsin Press.

Scarano, Francisco A. and Katherine J. Curtis White. 2005. “Population Growth and Agrarian Change in the Spanish Caribbean: Evidence from Puerto Rico’s *Padrones*, 1765-1815.” Unpublished manuscript.

Steward, Julian H., Robert A. Manners, Eric R. Wolf, Elena Padilla Seda, Sidney W. Mintz, and Raymond L. Scheefe. 1956. *The People of Puerto Rico: A Study in Social Anthropology*. Urbana, IL: University of Illinois Press.

Velyvis, Kristen, Theresa Thompson-Colón, and Halliman Winsborough. 2006. “Public Use Samples of 1910 and 1920 Puerto Rico Censuses.” *CDE Working Paper Series* 2006-1.

Wagley, Charles. 1960. “Plantation America: A Culture Sphere.” Pp. 3-13 in *Caribbean Studies: A Symposium* by Vera Rubin (Ed.). Seattle, WA: University of Washington Press.

Table 1. Descriptive Statistics for Individual-Level and Municipio-Level Data, Pooled and Separately by Year (Weighted)

	Pooled (N = 135,941)		1910 (N = 89,510)		1920 (N = 46,431)	
Individual-Level Factors	Mean	SD	Mean	SD	Mean	SD
Literate	0.34	0.43	0.31	0.42	0.39	0.45
Industry						
Sugar Farming	0.15	0.32	0.11	0.29	0.21	0.38
Tobacco Farming	0.03	0.16	0.01	0.09	0.08	0.24
Coffee Farming	0.07	0.24	0.05	0.20	0.12	0.30
Other Farming	0.16	0.34	0.15	0.33	0.18	0.35
Non-Farming Industry	0.59	0.45	0.68	0.43	0.41	0.46
Nativity/Race						
Native	0.98	0.12	0.98	0.12	0.98	0.12
Black	0.05	0.20	0.05	0.20	0.05	0.20
Mulatto	0.27	0.41	0.30	0.42	0.23	0.39
White	0.68	0.43	0.66	0.44	0.72	0.41
Other Race	0.00	0.00	0.00	0.00	0.00	0.00
Marital Status						
Married	0.33	0.43	0.30	0.42	0.38	0.45
Consensual Union	0.13	0.31	0.13	0.31	0.14	0.32
Divorced/Widowed	0.06	0.22	0.06	0.21	0.07	0.23
Single	0.48	0.46	0.52	0.46	0.41	0.45
Household Status						
Simple Family Household	0.43	0.46	0.43	0.45	0.44	0.46
Complex Family Household	0.52	0.46	0.53	0.46	0.50	0.46
Non-Family Household	0.05	0.20	0.04	0.19	0.06	0.21
Male	0.60	0.45	0.50	0.46	0.79	0.38
Age (Continuous)	30.37	13.66	28.61	13.69	33.71	13.04
	Pooled (N = 136)		**1910 (N = 68)**		**1920 (N = 68)**	
Municipio-Level Factors	Mean	SD	Mean	SD	Mean	SD
Proportion Literate (Proportion 10 YO+)	0.37	0.10	0.31	0.09	0.42	0.07
Crop Production (Proportion of Farm Acreage)						
Sugar Acreage	0.09	0.09	0.08	0.07	0.11	0.10
Tobacco Acreage	0.02	0.03	0.01	0.02	0.02	0.04
Coffee Acreage	0.08	0.10	0.07	0.10	0.08	0.11
Other Farm Acreage	0.81	0.10	0.84	0.09	0.78	0.10
Population Size (per 10,000)	1.78	1.23	1.64	1.10	1.91	1.34
Nativity (Proportion of White Population)						
Native Born	0.99	0.01	0.99	0.02	0.99	0.01
Spanish Foreign-Born	0.61	0.29	0.70	0.19	0.53	0.35
Race (Proportion of Total Population)						
Black	0.04	0.04	0.04	0.04	0.04	0.04
Mulatto	0.28	0.13	0.31	0.13	0.25	0.13
White	0.68	0.16	0.65	0.15	0.72	0.15
Other Race	0.00	0.00	0.00	0.00	0.00	0.00

Note: Individual-level sample contains population 10 years-old and older with complete information on all listed variables. Municipio-level sample includes all municipios in 1910 and 1920; data on municipios established in 1920 is merged with the corresponding 1910 municipio.

Table 2. Logistic Regression Analysis of Individual-Level Literacy with Tests for Non-Linearity in Key Predictors by Time, 1910-1920 Pooled PUMS (Weighted)

	Model 1			Model 2			Model 3			Model 4		
Individual-Level Factors	β	SE	Exp(β)	β	SE	Exp(β)	β	SE	Exp(β)	β	SE	Exp(β)
Constant	1.34 ***	0.16	3.82	0.78 ***	0.43	2.19	1.35 ***	0.16	3.84	1.38 ***	0.17	3.99
Industry												
Sugar Farming	-1.56 ***	0.05	0.21	-1.56 ***	0.05	0.21	-1.56 ***	0.05	0.21	-1.56 ***	0.05	0.21
Tobacco Farming	-1.42 ***	0.08	0.24	-1.42 ***	0.08	0.24	-1.42 ***	0.08	0.24	-1.42 ***	0.08	0.24
Coffee Farming	-1.44 ***	0.07	0.24	-1.44 ***	0.07	0.24	-1.44 ***	0.07	0.24	-1.43 ***	0.07	0.24
Other Farming	-1.30 ***	0.05	0.27	-1.30 ***	0.05	0.27	-1.30 ***	0.05	0.27	-1.30 ***	0.05	0.27
Non-Farming Industry	-	-	-	-	-	-	-	-	-	-	-	-
Nativity/Race												
Native	-2.40 ***	0.18	0.09	-1.84 ***	0.48	0.16	-2.40 ***	0.18	0.09	-2.39 ***	0.18	0.09
Black	-0.56 ***	0.07	0.57	-0.56 ***	0.07	0.57	-0.66 **	0.21	0.52	-0.56 ***	0.07	0.57
Mulatto	-0.57 ***	0.04	0.57	-0.57 ***	0.04	0.57	-0.57 ***	0.04	0.57	-0.75 ***	0.12	0.47
White/Other Race	-	-	-	-	-	-	-	-	-	-	-	-
Marital Status												
Married	0.08 **	0.02	1.08	0.08 **	0.02	1.08	0.08 **	0.02	1.08	0.08 **	0.02	1.08
Consensual Union	-0.61 ***	0.04	0.54	-0.61 ***	0.04	0.54	-0.61 ***	0.04	0.54	-0.61 ***	0.04	0.54
Divorced/Widowed	0.00	0.05	1.00	0.00	0.05	1.00	0.00	0.05	1.00	0.00	0.05	1.00
Single	-	-	-	-	-	-	-	-	-	-	-	-
Household Status												
Simple Family Household	-	-	-	-	-	-	-	-	-	-	-	-
Complex Family Household	0.30 ***	0.02	1.36	0.30 ***	0.02	1.36	0.30 ***	0.02	1.36	0.30 ***	0.02	1.36
Non-Family Household	0.20 ***	0.06	1.22	0.20 ***	0.06	1.22	0.20 ***	0.06	1.22	0.20 ***	0.06	1.22
Male	1.05 ***	0.06	2.86	1.05 ***	0.06	2.86	1.05 ***	0.06	2.86	1.05 ***	0.06	2.86
Age (Continuous)	-0.02 ***	0.00	0.98	-0.02 ***	0.00	0.98	-0.02 ***	0.00	0.98	-0.02 ***	0.00	0.98
Year	0.06 ***	0.01	1.07	0.11 ***	0.03	1.11	0.06 ***	0.01	1.07	0.06 ***	0.01	1.06
Temporal Interactions												
Native x Year	-	-	-	-0.04	0.03	0.96	-	-	-	-	-	-
Black x Year	-	-	-	-	-	-	0.01	0.01	1.01	-	-	-
Mulatto x Year	-	-	-	-	-	-	-	-	-	0.01 †	0.01	1.01
Sugar x Year	-	-	-	-	-	-	-	-	-	-	-	-
Variance Component (Constant)	0.137			0.137			0.137			0.137		
Variance Component (Error)	0.921			0.921			0.921			0.921		

† p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001

Note: Estimated using HLM (N=135,941).

Table 3. Multilevel Regression Analysis with Tests for Cross-Level Associations between Nativity/Race and Ecological Factors, Pooled PUMS and Census Municipio Data (Weighted)

	Model 1			Model 2		
	β	SE	Exp(β)	β	SE	Exp(β)
Individual-Level Factors						
Constant	-4.03	2.19	0.02	-3.09	2.32	0.05
Industry						
Sugar Farming	-1.60 ***	0.05	0.20	-1.60 ***	0.05	0.20
Tobacco Farming	-1.44 ***	0.08	0.24	-1.44 ***	0.08	0.24
Coffee Farming	-1.48 ***	0.07	0.23	-1.48 ***	0.07	0.23
Other Farming	-1.33 ***	0.05	0.26	-1.33 ***	0.05	0.26
Non-Farming Industry	-	-	-	-	-	-
Nativity/Race						
Native	-2.58 ***	0.15	0.08	-2.92 ***	0.20	0.05
Black	-0.60 ***	0.08	0.55	-0.60 ***	0.08	0.55
Mulatto	-0.59 ***	0.04	0.55	-0.59 ***	0.04	0.55
White/Other Race	-	-	-	-	-	-
Marital Status						
Married	0.08 **	0.03	1.08	0.08 **	0.03	1.08
Consensual Union	-0.63 ***	0.04	0.53	-0.63 ***	0.04	0.53
Divorced/Widowed	0.00	0.04	1.00	-0.01	0.04	0.99
Single	-	-	-	-	-	-
Household Status						
Simple Family Household	-	-	-	-	-	-
Complex Family Household	0.31 ***	0.02	1.37	0.31 ***	0.02	1.37
Non-Family Household	0.21 ***	0.06	1.23	0.21 ***	0.06	1.23
Male	1.10 ***	0.04	3.01	1.10 ***	0.04	3.01
Age (Continuous)	-0.02 ***	0.00	0.98	-0.02 ***	0.00	0.98
Year	0.01	0.01	1.01	0.01	0.01	1.01
Municipio-Level Factors						
Proportion Literate	4.77 ***	0.32	117.57	4.75 ***	0.32	115.73
Crop Production						
Sugar Acreage	0.30	0.25	1.35	0.60	0.55	1.83
Tobacco Acreage	1.74 *	0.83	5.70	1.74 *	0.83	5.71
Coffee Acreage	0.56 ***	0.21	1.74	0.54 **	0.20	1.72
Other Farm Acreage	-	-	-	-	-	-
Population Size	-0.03 *	0.02	0.97	-0.01	0.02	0.99
Nativity Proportions						
Native Born	4.51 *	2.21	90.54	3.87	2.30	47.70
Spanish Foreign-Born	-0.07	0.06	0.93	-0.07	0.06	0.94
Race Proportions						
Black	0.62	0.39	1.86	0.53	0.40	1.71
Mulatto	0.56 ***	0.13	1.75	0.56 ***	0.13	1.76
White/Other Race	-	-	-	-	-	-
Sugar Acreage x Population Size				-1.08 ***	0.31	0.34
Cross-Level Interactions						
Native x Sugar Acreage x Population Size	-	-	-	0.91 ***	0.25	2.49
Black x Sugar Acreage x Population Size	-	-	-	-	-	-
Mulatto x Sugar Acreage x Population Size	-	-	-	-	-	-
Variance Component (Constant)	0.018			0.018		
Variance Component (Error)	0.922			0.921		

Table 3. Continued

	Model 3			Model 4		
	β	SE	Exp(β)	β	SE	Exp(β)
Individual-Level Factors						
Constant	-3.16	2.38	0.04	-3.79	2.32	0.02
Industry						
Sugar Farming	-1.60 ***	0.05	0.20	-1.60 ***	0.05	0.20
Tobacco Farming	-1.44 ***	0.08	0.24	-1.44 ***	0.08	0.24
Coffee Farming	-1.48 ***	0.07	0.23	-1.48 ***	0.07	0.23
Other Farming	-1.33 ***	0.05	0.26	-1.33 ***	0.05	0.26
Non-Farming Industry	-	-	-	-	-	-
Nativity/Race						
Native	-2.58 ***	0.16	0.08	-2.58 ***	0.15	0.08
Black	-0.60 ***	0.04	0.55	-0.59 ***	0.08	0.55
Mulatto	-0.59 ***	0.04	0.55	-0.66 ***	0.04	0.51
White/Other Race	-	-	-	-	-	-
Marital Status						
Married	0.08 **	0.03	1.08	0.08 **	0.03	1.08
Consensual Union	-0.63 ***	0.04	0.53	-0.63 ***	0.04	0.53
Divorced/Widowed	0.00	0.04	1.00	0.00	0.04	1.00
Single	-	-	-	-	-	-
Household Status						
Simple Family Household	-	-	-	-	-	-
Complex Family Household	0.31 ***	0.02	1.37	0.31 ***	0.02	1.37
Non-Family Household	0.21 ***	0.06	1.23	0.21 ***	0.06	1.23
Male	1.10 ***	0.04	3.01	1.10 ***	0.04	3.01
Age (Continuous)	-0.02 ***	0.00	0.98	-0.02 ***	0.00	0.98
Year	0.01	0.01	1.01	0.01	0.01	1.01
Municipio-Level Factors						
Proportion Literate	4.75 ***	0.32	115.43	4.77 ***	0.32	118.38
Crop Production						
Sugar Acreage	0.60	0.54	1.82	0.61	0.55	1.84
Tobacco Acreage	1.73 *	0.83	5.63	1.74 *	0.84	5.70
Coffee Acreage	0.54 **	0.20	1.71	0.54 **	0.20	1.72
Other Farm Acreage	-	-	-	-	-	-
Population Size	-0.01	0.02	0.99	-0.01	0.02	0.99
Nativity Proportions						
Native Born	3.60	2.41	36.64	4.24 †	2.35	69.17
Spanish Foreign-Born	-0.07	0.06	0.93	-0.07	0.06	0.94
Race Proportions						
Black	0.45	0.41	1.57	0.54	0.40	1.71
Mulatto	0.56 **	0.13	1.75	0.60 ***	0.13	1.83
White/Other Race	-	-	-	-	-	-
Sugar Acreage x Population Size	-0.16	0.21	0.86	-0.23	0.21	0.79
Cross-Level Interactions						
Native x Sugar Acreage x Population Size	-	-	-	-	-	-
Black x Sugar Acreage x Population Size	-0.30	0.21	0.74	-	-	-
Mulatto x Sugar Acreage x Population Size	-	-	-	0.24 †	0.14	1.27
Variance Component (Constant)	0.017			0.018		
Variance Component (Error)	0.922			0.922		

† p < 0.10, * p < 0.05, ** p < 0.01, *** p < 0.001

Note: Estimated using HLM (N=135,941; Census N=136).

Table 4. Multilevel Regression Analysis with Tests for Cross-Level Associations between Nativity/Ancestry and Ecological Factors, Pooled PUMS and Census Municipio Data (Weighted)

	β		SE	Exp(β)
Individual-Level Factors				
Constant	-5.68	*	2.48	0.00
Industry				
Sugar Farming	-1.58	***	0.05	0.21
Tobacco Farming	-1.42	***	0.08	0.24
Coffee Farming	-1.46	***	0.07	0.23
Other Farming	-1.32	***	0.05	0.27
Non-Farming Industry	-		-	-
Nativity/Ancestry				
Native	-1.71	***	0.23	0.18
Spanish Descent	2.15	***	0.12	8.60
U.S. Descent	3.00	***	0.51	20.03
Race				
Black	-0.53	***	0.08	0.59
Mulatto	-0.55	***	0.04	0.58
White/Other Race	-		-	-
Marital Status				
Married	0.08	**	0.03	1.08
Consensual Union	-0.62	***	0.04	0.54
Divorced/Widowed	-0.01		0.04	0.99
Single	-		-	-
Household Status				
Simple Family Household	-		-	-
Complex Family Household	0.30	***	0.02	1.35
Non-Family Household	0.19	***	0.06	1.21
Male	1.09	***	0.04	2.99
Age (Continuous)	-0.02	***	0.00	0.98
Year	0.01		0.01	1.01
Municipio-Level Factors				
Proportion Literate	4.86	***	0.32	128.40
Crop Production				
Sugar Acreage	0.53		0.55	1.70
Tobacco Acreage	1.73	*	0.83	5.65
Coffee Acreage	0.52	**	0.20	1.68
Other Farm Acreage	-		-	-
Population Size	-0.02		0.02	0.98
Nativity Proportions				
Native Born	5.24	*	2.45	187.96
Spanish Foreign-Born	-0.12	†	0.06	0.89
Race Proportions				
Black	0.60		0.40	1.82
Mulatto	0.57	***	0.13	1.76
White/Other Race	-		-	-
Sugar Acreage x Population Size	-0.09		0.34	0.92
Cross-Level Interactions				
Native x Sugar Acreage x Population Size	-0.04		0.27	0.96
Spanish Descent x Sugar Acreage x Population Size	-0.95	***	0.24	0.39
U.S. Descent x Sugar Acreage x Population Size	-2.28	**	0.81	0.10
Variance Component (Constant)	0.017			
Variance Component (Error)	0.921			

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Estimated using HLM (N=135,941; Census N=136).

Table 1A. Ranked Proportion Literate by Municipio, 1910-1920 PUMS Pooled and Separately by Year (Weighted)

	Pooled				1910				1920		
	N	Mean	SD		N	Mean	SD		N	Mean	SD
Puerto Rico Total	135,941	0.34	0.43	Puerto Rico Total	89,510	0.31	0.42	Puerto Rico Total	46,431	0.39	0.45
[1] SAN JUAN	5,981	0.69	0.46	SAN JUAN	3,609	0.68	0.47	SAN JUAN	2,372	0.69	0.46
[2] CULEBRA	106	0.63	0.48	CULEBRA	93	0.68	0.47	MAYAGUEZ	2,931	0.55	0.36
[3] MAYAGUEZ	8,729	0.49	0.36	MAYAGUEZ	5,798	0.46	0.35	PONCE	2,533	0.52	0.48
[4] PONCE	7,086	0.47	0.48	PONCE	4,553	0.44	0.48	LAJAS	375	0.49	0.50
[5] VIEQUES	1,168	0.43	0.49	VIEQUES	695	0.42	0.49	SALINAS	513	0.48	0.50
[6] GUAYAMA	1,840	0.41	0.49	CABO ROJO	1,343	0.40	0.49	BAYAMON	1,131	0.47	0.50
[7] AGUADILLA	2,173	0.41	0.49	GUAYAMA	1,190	0.40	0.49	RIO PIEDRAS	770	0.46	0.50
[8] CABO ROJO	2,179	0.41	0.49	AGUADILLA	1,458	0.39	0.49	YAUCO	1,137	0.46	0.47
[9] BAYAMON	3,058	0.39	0.49	SANTA ISABEL	491	0.36	0.48	AGUADILLA	715	0.45	0.50
[10] LAJAS	1,139	0.39	0.49	BAYAMON	1,927	0.35	0.48	VIEQUES	473	0.44	0.50
[11] SANTA ISABEL	750	0.37	0.48	LAJAS	764	0.34	0.47	GUAYAMA	650	0.43	0.50
[12] RIO PIEDRAS	1,927	0.37	0.48	QUEBRADILLAS	576	0.33	0.47	TOA BAJA	241	0.42	0.49
[13] SALINAS	1,212	0.37	0.48	YAUCO	2,334	0.33	0.45	SAN GERMAN	833	0.41	0.49
[14] YAUCO	3,471	0.37	0.46	COAMO	1,198	0.33	0.47	CABO ROJO	836	0.41	0.49
[15] SAN GERMAN	2,309	0.36	0.48	TOA BAJA	485	0.32	0.47	CAMUY	444	0.41	0.49
[16] TOA BAJA	726	0.36	0.48	SAN GERMAN	1,476	0.32	0.47	SANTA ISABEL	259	0.41	0.49
[17] QUEBRADILLAS	839	0.35	0.48	SABANA GRANDE	765	0.32	0.47	QUEBRADILLAS	263	0.40	0.49
[18] COAMO	1,730	0.34	0.47	FAJARDO	1,385	0.32	0.47	ARECIBO	1,430	0.39	0.49
[19] FAJARDO	2,105	0.34	0.47	RIO PIEDRAS	1,157	0.31	0.46	LOIZA	771	0.39	0.35
[20] CAYEY	2,004	0.33	0.47	CAYEY	1,163	0.31	0.46	LAS MARIAS	616	0.38	0.34
[21] CAMUY	1,250	0.33	0.47	SALINAS	699	0.29	0.46	COAMO	532	0.38	0.48
[22] ARECIBO	4,357	0.31	0.46	ARROYO	412	0.29	0.45	BARRANQUITAS	292	0.37	0.48
[23] SABANA GRANDE	1,150	0.31	0.46	JUNCOS	783	0.28	0.45	FAJARDO	720	0.37	0.48
[24] ANASCO	1,569	0.31	0.44	ANASCO	1,105	0.28	0.43	ANASCO	464	0.37	0.46
[25] MANATI	1,830	0.31	0.46	AIBONITO	658	0.28	0.45	GUAYANILLA	292	0.37	0.48
[26] BARRANQUITAS	992	0.30	0.46	CAMUY	806	0.28	0.45	ADJUNTAS	1,017	0.37	0.34
[27] CAGUAS	2,966	0.30	0.46	MANATI	1,160	0.28	0.45	MANATI	670	0.36	0.48
[28] LAS MARIAS	1,936	0.30	0.32	CAGUAS	1,780	0.27	0.45	SAN SEBASTIAN	1,293	0.36	0.34
[29] JUNCOS	1,170	0.30	0.46	MARICAO	970	0.27	0.31	CAYEY	841	0.36	0.48
[30] AIBONITO	1,082	0.30	0.46	ARECIBO	2,927	0.27	0.44	MARICAO	491	0.35	0.34
[31] MARICAO	1,461	0.30	0.32	BARRANQUITAS	700	0.27	0.45	RIO GRANDE	348	0.35	0.48
[32] LOIZA	2,448	0.30	0.32	CAROLINA	1,066	0.27	0.44	PENUELAS	423	0.35	0.48
[33] CAROLINA	1,533	0.29	0.46	LAS MARIAS	1,320	0.26	0.31	BARCELONETA	399	0.35	0.48
[34] SAN SEBASTIAN	3,734	0.29	0.32	DORADO	342	0.26	0.44	DORADO	194	0.35	0.48
[35] DORADO	536	0.29	0.45	PATILLAS	1,010	0.26	0.44	CAROLINA	467	0.34	0.48
[36] BARCELONETA	1,171	0.29	0.45	BARCELONETA	772	0.26	0.44	HATILLO	442	0.34	0.47
[37] RIO GRANDE	1,273	0.28	0.45	JUANA DIAZ	2,733	0.25	0.37	LARES	1,401	0.34	0.34
[38] ARROYO	594	0.28	0.45	SAN SEBASTIAN	2,441	0.25	0.31	CAGUAS	1,186	0.34	0.47
[39] HATILLO	1,227	0.27	0.45	RIO GRANDE	925	0.25	0.44	UTUADO	2,701	0.34	0.33
[40] TRUJILLO ALTO	681	0.27	0.45	LOIZA	1,677	0.25	0.31	MAUNABO	205	0.34	0.47
[41] GUAYANILLA	984	0.27	0.45	TRUJILLO ALTO	463	0.25	0.44	JUNCOS	387	0.33	0.47
[42] MAUNABO	719	0.27	0.45	MAUNABO	514	0.25	0.43	NAGUABO	454	0.33	0.47
[43] JUANA DIAZ	4,003	0.27	0.38	HATILLO	785	0.24	0.43	AIBONITO	424	0.33	0.47
[44] PATILLAS	1,411	0.27	0.44	VEGA ALTA	532	0.24	0.43	SAN LORENZO	520	0.32	0.47
[45] ADJUNTAS	3,290	0.27	0.31	GUAYANILLA	692	0.23	0.42	TRUJILLO ALTO	218	0.32	0.47
[46] LARES	4,494	0.26	0.31	HUMACAO	1,784	0.23	0.42	ISABELLA	636	0.32	0.47
[47] UTUADO	8,141	0.26	0.31	GURABO	674	0.23	0.42	COROZAL	323	0.32	0.47
[48] PENUELAS	1,227	0.26	0.44	LARES	3,093	0.23	0.30	AGUAS BUENAS	359	0.31	0.47
[49] NAGUABO	1,409	0.26	0.44	VEGA BAJA	924	0.23	0.42	HUMACAO	850	0.31	0.46
[50] HUMACAO	2,634	0.26	0.44	UTUADO	5,440	0.23	0.30	VEGA BAJA	461	0.31	0.46
[51] VEGA ALTA	778	0.26	0.44	NAGUABO	955	0.23	0.42	YABUCOA	590	0.31	0.46
[52] VEGA BAJA	1,385	0.26	0.44	ADJUNTAS	2,273	0.22	0.29	CULEBRA	13	0.31	0.48
[53] ISABELLA	1,813	0.25	0.44	ISABELLA	1,177	0.22	0.41	BARROS	381	0.30	0.46
[54] CIDRA	1,073	0.24	0.43	MOROVIS	790	0.22	0.41	JUANA DIAZ	1,270	0.30	0.40
[55] YABUCOA	1,773	0.24	0.43	PENUELAS	804	0.21	0.41	VEGA ALTA	246	0.30	0.46
[56] SAN LORENZO	1,485	0.24	0.43	CIALES	2,424	0.21	0.29	PATILLAS	401	0.30	0.46
[57] MOROVIS	1,180	0.23	0.42	CIDRA	702	0.21	0.41	CIDRA	371	0.30	0.46
[58] GURABO	1,208	0.23	0.42	COMERIO	746	0.21	0.41	TOA ALTA	282	0.28	0.45
[59] COMERIO	1,241	0.23	0.42	NARANJITO	606	0.21	0.41	SABANA GRANDE	385	0.28	0.45
[60] AGUAS BUENAS	878	0.23	0.42	YABUCOA	1,183	0.20	0.40	CIALES	1,059	0.27	0.31
[61] CIALES	3,483	0.23	0.30	TOA ALTA	547	0.20	0.40	MOROVIS	390	0.27	0.45
[62] TOA ALTA	829	0.23	0.42	BARROS	1,087	0.19	0.39	RINCON	300	0.27	0.44
[63] COROZAL	1,142	0.22	0.42	SAN LORENZO	965	0.19	0.39	COMERIO	495	0.27	0.44
[64] BARROS	1,468	0.22	0.42	COROZAL	819	0.18	0.39	MOCA	480	0.26	0.44
[65] NARANJITO	912	0.22	0.41	AGUADA	829	0.17	0.38	NARANJITO	306	0.25	0.43
[66] MOCA	1,423	0.20	0.40	AGUAS BUENAS	519	0.17	0.38	ARROYO	182	0.24	0.43
[67] AGUADA	1,272	0.19	0.40	MOCA	943	0.17	0.37	GURABO	534	0.24	0.43
[68] RINCON	794	0.19	0.39	RINCON	494	0.14	0.34	AGUADA	443	0.23	0.42

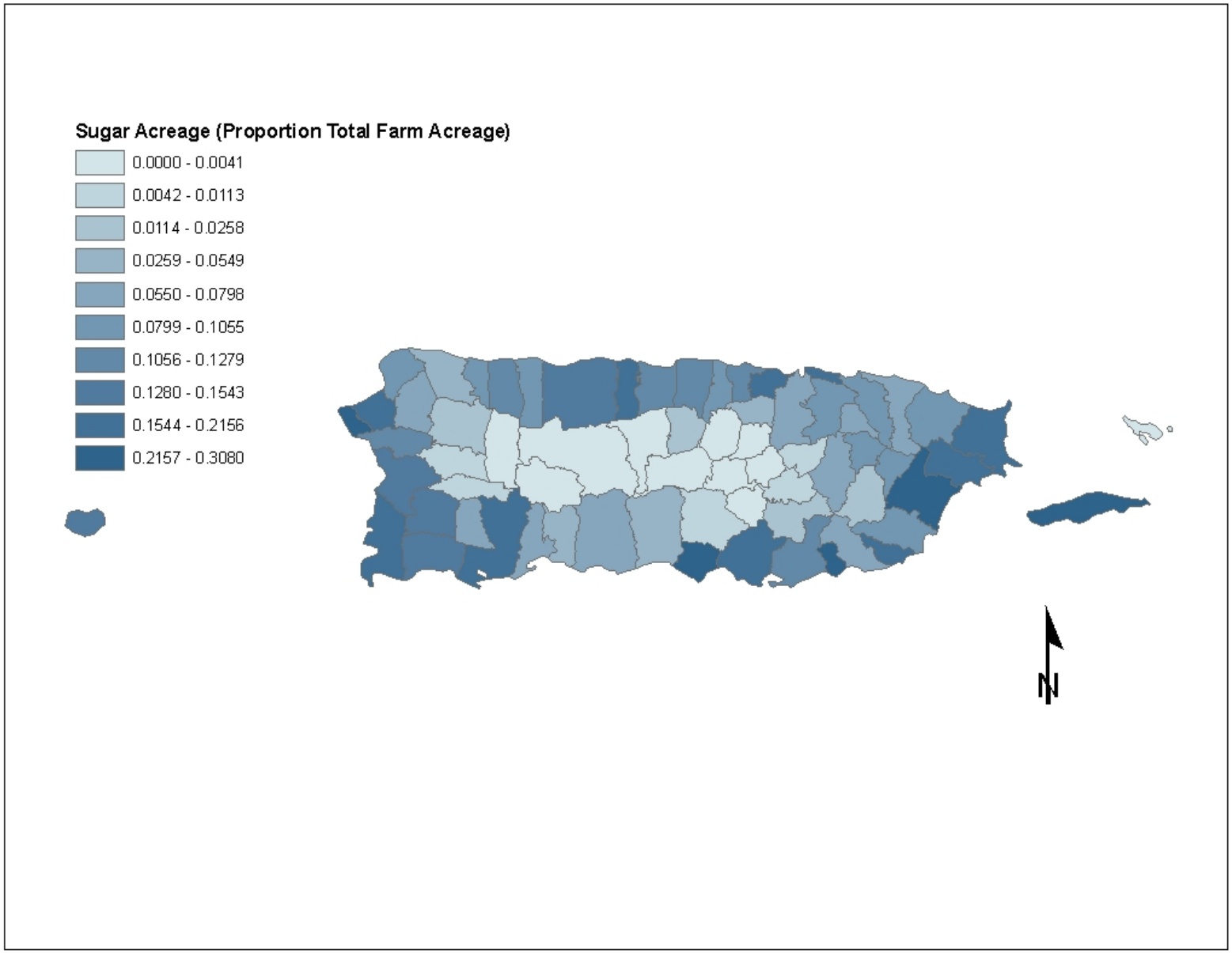

Figure 1. Map of Sugar Acreage for Puerto Rico Municipios (N=68)

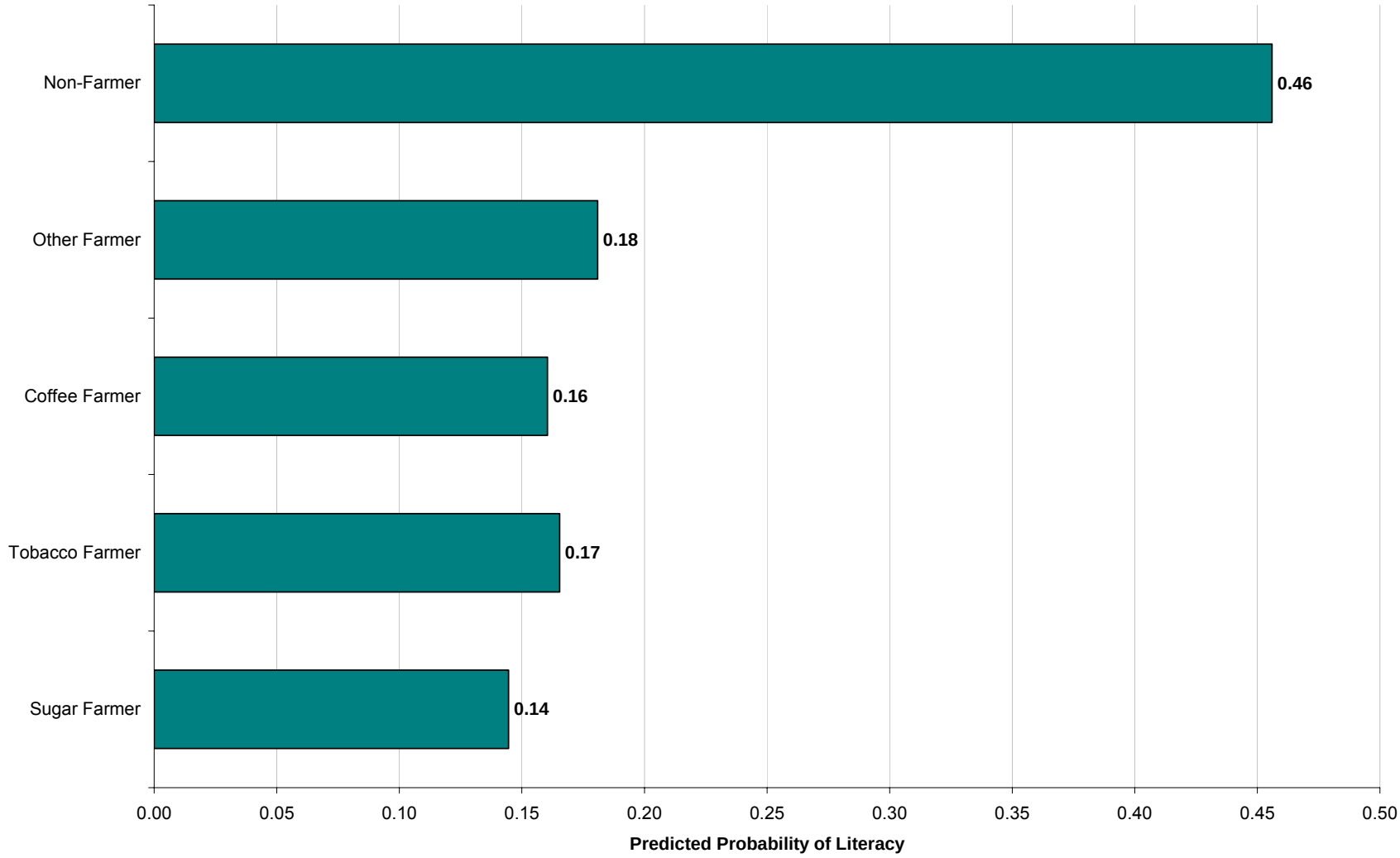

Figure 2. Predicted Probability of Literacy by Individual Industry

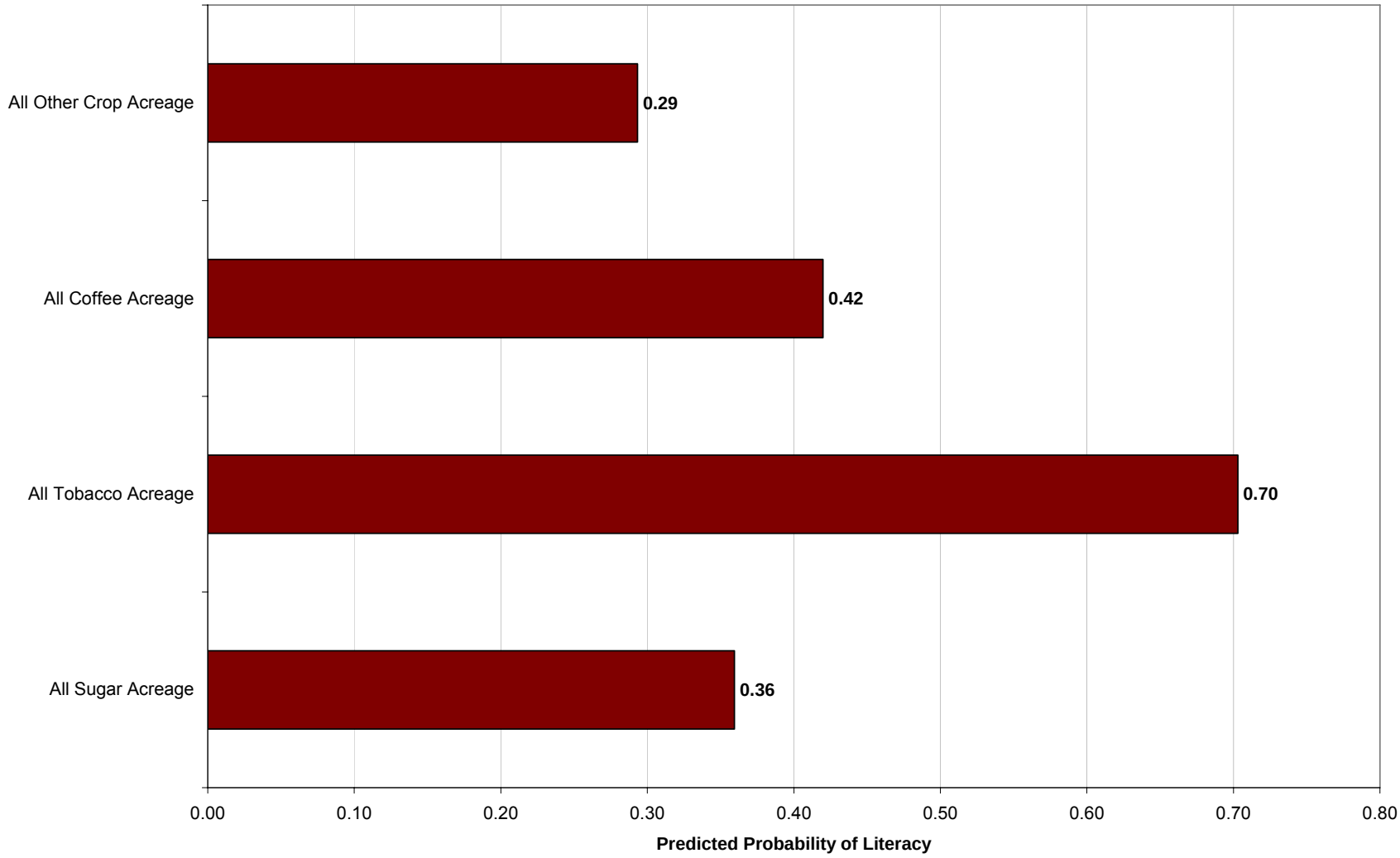

Figure 3. Predicted Probability of Literacy by Municipio Crop Acreage

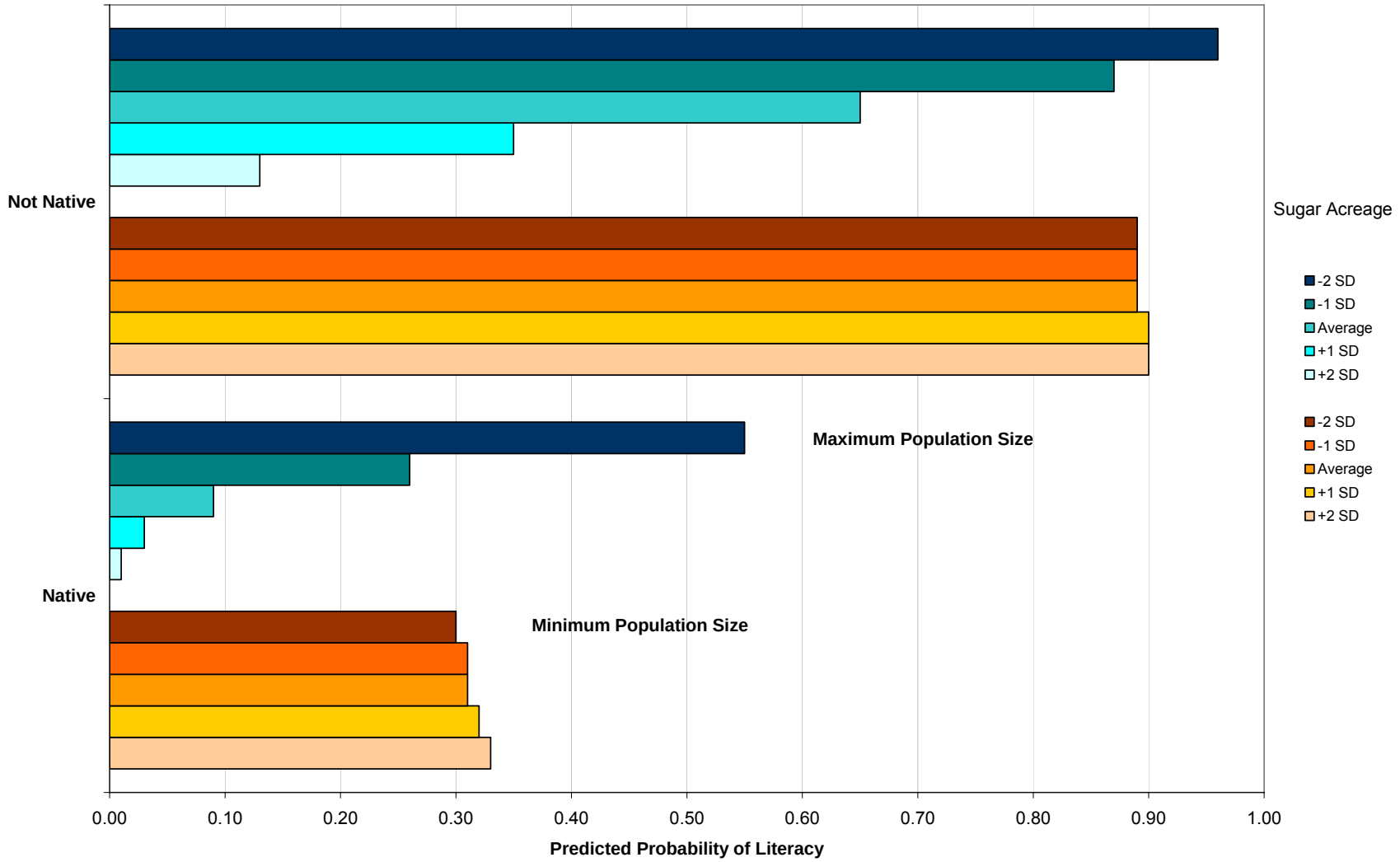

Figure 4. Predicted Probability of Literacy for Natives and Non-Natives by Sugar Acreage, for Maximum and Minimum Population

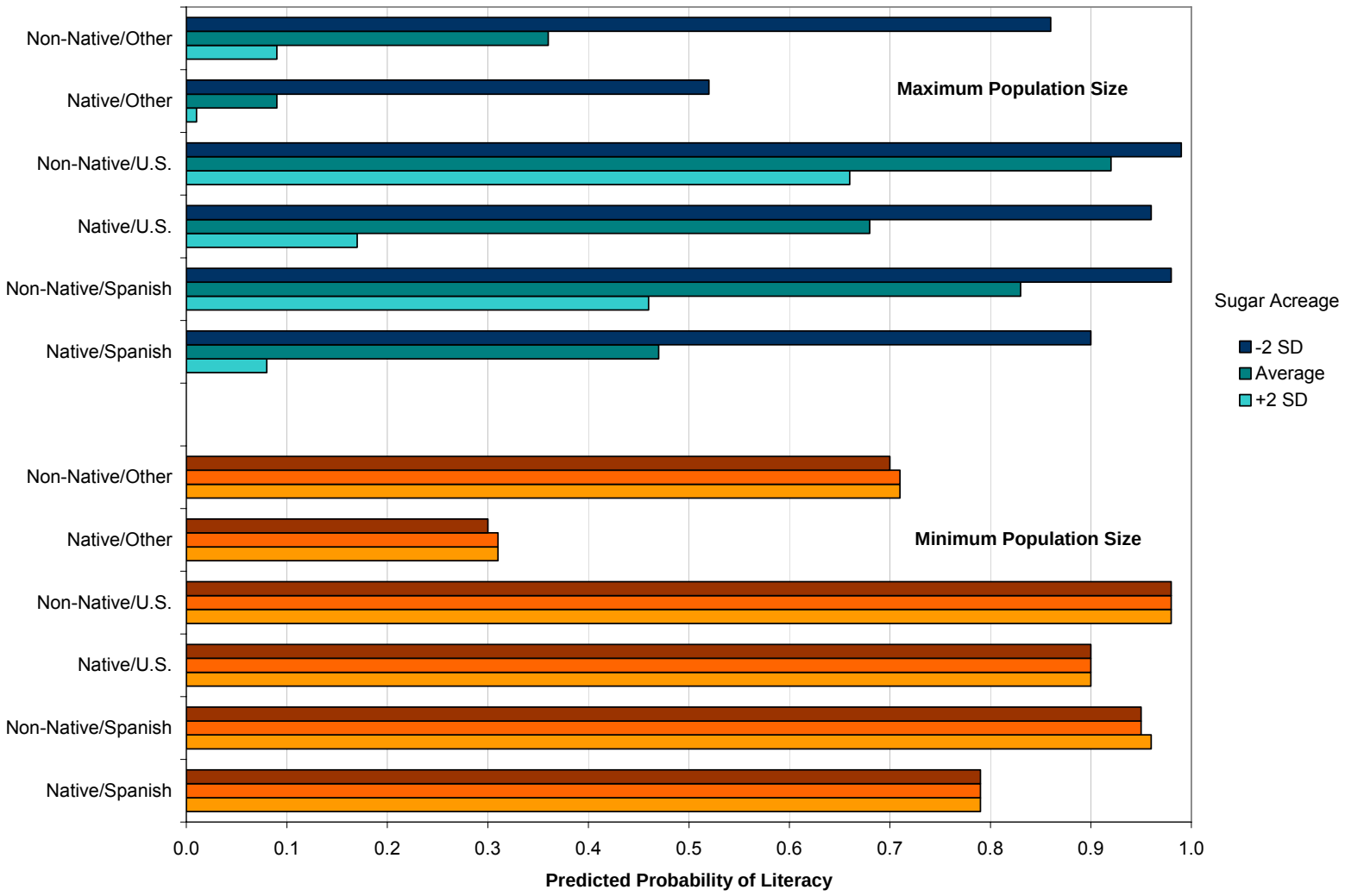

Figure 5. Predicted Probability of Literacy for Natives and Non-Natives according to Ancestry by Sugar Acreage, for Maximum and Minimum Population