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Supplement to:

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Appendix A. Cross-Survey Multiple Imputation Methodology

The NHANES and NHIS have complementary strengths. The NHANES includes all of the variables we need to conduct our analysis, including retrospective measures of height and weight at age 25, but its sample is too small to power our statistical analysis and comparisons of foreign-born Hispanics and whites. Conversely, the NHIS has a much larger sample but it lacks the required retrospective measures of height and weight that we need for our study. In cases such as this, cross-sample multiple imputation (CSMI) can help tap the strengths of both data sources by pooling them and multiply imputing the missing variables in the data source that lacks the measures (Rendall et al. 2013). This technique has been used to study children of immigrants' weight trajectories (Baker, Rendall, and Weden 2015) and to impute immigrants' legal status in large surveys such as the American Community Survey (Van Hook et al., 2015; Capps, Bachmeier and Van Hook 2018). For this study, we used CSMI to examine how cohort changes in smoking and obesity in early life may change the shape of the Hispanic life expectancy paradox.

CSMI can yield unbiased estimates and greatly increase statistical power. Indeed, one of the major assumptions of multiple imputation is that data are missing at random (MAR). This assumption is easily satisfied, because in our case, missingness is largely a consequence of a question not being asked or a variable not being measured in the NHIS. Because the NHIS and NHANES samples are randomly selected, missingness is also random. However, the CSMI method also depends on the satisfaction of two other major assumptions. First, all analytic variables must be jointly observed, meaning that at least one of the pooled data sets includes the full set of analytic variables. This is referred to as the "no never-jointly-observed variables" assumption. Inclusion of never-jointly-observed variables can yield biased estimates (Rendall et al 2013; Van Hook et al., 2015). In the illustration below (Table A1a), data set 1 includes Y, X1, and X2, and data set 2 includes Y, X2 and X3. In this situation, X1 and X3 are never jointly observed. If an analyst were to pool data sets 1 and 2 and attempt to impute values for X1 and X3, there would exist no cases on which to estimate the association between the two variables. However, if data set 1 included Y, X1, X2, and X3 (Table A1b), then the assumption would be satisfied.

Table A1a. Never-Jointly-Observed Variables: Assumption 1 Not Met

Variables	Data Set 1	Data Set 2
Y	observed	Observed
X1	observed	--
X2	observed	Observed
X3	--	Observed

Table A1b. No Never-Jointly-Observed Variables: Assumption 1 Met

Variables	Data Set 1	Data Set 2
Y	observed	Observed
X1	observed	--
X2	observed	Observed
X3	observed	Observed

The second major assumption of CSMI is that the two data sources are drawn from the same underlying population. This ensures that the set of conditional associations observed in data set 1 can be assumed to hold for data set 2. This is referred to as the “same universe” assumption.

In the next two sections, we describe the steps we took to meet both assumptions and implement the CSMI method. We first provide details for those who wish to replicate our work and demonstrate that we have adhered to the “no never-jointly-observed variables” assumption. We then describe the results of tests we conducted of the same-universe assumption.

Section A: Relevant Details to Replicate our CSMI Analysis

We followed three steps to implement CSMI: (1) data harmonization, (2) pooling and imputation, and (3) detachment and analysis.

In the first step, we harmonized the samples and measures in each data source. We limited the samples to the same cohorts (born in 1920 or later and age 25-84 at interview) and demographic groups (non-Hispanic whites, foreign-born Mexicans, and U.S.-born Mexicans). We further restricted the NHANES sample to adults who participated in physical examinations (during which their weight and height measurements were taken). The NHIS sample was restricted to adults who answered questions about their weight and height. Both samples were limited to those eligible for mortality follow-up.

We coded all analytic and auxiliary variables using the same metrics or categories. Analytic variables included mortality status, height (inches) and weight (lbs.) at age 25, smoking status and duration at age 25, age and year of interview, educational attainment, and ethnicity/nativity status. Height and weight at age 25 were unobserved in the NHIS so they were treated as missing for all NHIS respondents. Auxiliary measures, used to inform the imputation, included current height (inches) and weight (lbs.) and the average *cohort* height and weight in early adulthood (age 20-29). Current height and weight were measured in the NHANES but self-reported in the NHIS, so we adjusted the self-reported height and weight measures in the NHIS at the data harmonization stage[1]. Our approach is similar to the one used by Cawley (2004) but takes the additional step of accounting for the association of reporting error with the dependent

[1] That is, we pooled the NHIS, which contains only self-reported height and weight, with NHANES data, which contains both self-reported and measured height and weight. We treated measured height and weight in the NHIS as missing and imputed it as a function of all of the analytic variables. The imputation model was stratified by ethnicity/nativity, and gender, allowing for the adjustment to differ across groups. This does not violate the "no never-jointly observed" assumption because measured height and weight are missing in NHIS and not NHANES.

variable (mortality). Average cohort height and weight were estimated directly from the NHIS for a sample of young adults ages 20-29. We were able to use historical NHIS data to construct the cohort measures for those born in the 1950s and later.

As shown in Table A2, the NHIS sample is slightly older at death or censorship, more likely to have died during the mortality follow-up period, and more likely to be white, slightly more educated, and weigh a little less than those in the NHANES sample. That said, these differences tend to be substantively small. This analysis also demonstrates that we have adhered to the condition of no never-jointly-observed variables. Nearly all of the NHANES respondents (93%) have non-missing values for all analytic variables, and 57% have non-missing values for all analytic and auxiliary variables. This is despite the fact that all of the cases in the NHIS are missing on weight and height at age 25, and about half are missing on smoking duration at age 25 because questions about the age a person started smoking were asked of randomly selected adults in the NHIS before 1998. Additionally, two of the auxiliary variables – cohort average weight and height – are missing for 34% of the NHIS sample and 40% of the NHANES sample because they could not be constructed for those born before the 1950s.

Table A2. Means and Missingnesss of Analytic and Auxiliary Variables in NHIS and NHANES

	NHIS (N = 728,700)			NHANES (N=25,961)		
	Mean	SD[b]	% Missing	Mean	SD[b]	% Missing
Analytic Variables						
Mortality Status (1=died)	0.17		0.0	0.09		0.0
Age at death or censorship	62	14	0.0	58	15	0.0
Weight age 25 (lbs)			100.0	156	38	4.3
Height age 25 (inches)			100.0	67	4	0.0
Ever smoked by age 25	0.42		47.7	0.46		2.8
Years smoked by age 25	3.20	4.39	47.7	3.50	4.46	2.8
Year of interview	2000	8	0.0	2006	5	0.0
Age at interview	47.9	15.0	0.0	49.6	15.3	0.0
Sex (Female)	0.52		0.0	0.51		0.0
Ethnicity/Nativity						
White	0.89		0.0	0.85		0.0
FB Hispanic	0.07		0.0	0.10		0.0
USB Hispanic	0.04		0.0	0.05		0.0
Education						
Less than 9th grade	0.06		0.5	0.07		0.1
9th-11th grade	0.08		0.5	0.11		0.1
12th grade	0.34		0.5	0.24		0.1
Some post-secondary	0.25		0.5	0.29		0.1
College Graduate	0.27		0.5	0.29		0.1
Auxiliary Variables used to Inform Imputation						
Weight at Interview (lbs)	171	37	0.0	181	45	0.0
Height at interview (in.)	67	4	0.0	67	4	0.0
Average weight (lbs.) of cohort age 25[a]	164	18	43.0	165	18	39.6
Average height (in) of cohort age 25[a]	67	3	43.0	67	3	39.6

Notes: Sample is 1998-2014 National Health Interview Survey with Mortality Linkages and 1999-2014 National Health and Nutrition Examination Survey with Mortality Linkages. Sample restricted to adults ages 25-84 at interview who were eligible for mortality follow-up. 93% of NHANES cases have complete data on all analytic variables, and 57% have complete data on all analytic and auxiliary variables. [a]Calculated from adults ages 20-29 in NHIS; this variable is available for those born in the 1950s or later. [b]SD shown for continuous variables only.

After comparing the NHANES and NHIS samples, we pooled them and multiply imputed all missing values, including retrospective height and weight. We used the MI module in Stata, and employed the chained equations multiple imputation method, which uses sequential equations as recommended by Rendall and colleagues (2013). We stratified the imputation models by ethnicity/nativity and gender (6 groups total) because we later estimated means and models separately for these 6 groups. Categorical variables were imputed using ordered logit or logistic regression, and continuous variables were imputed using OLS regression. Height, weight, and duration smoked at age 25 were imputed as continuous variables and then recoded to categorical measures following imputation. We produced 5 imputed data sets to account for uncertainty in the imputed values. Although the recommended practice is to impute more data sets (Graham, Olchowski and Gilreath, 2007; Rendall et al 2013 used 20 imputed data sets in their illustration), the enormous sample sizes of the NHIS and the fact that we bootstrapped the standard errors of the life expectancy simulations over 500 iterations made it computationally prohibitive to do so.

One concern is that the retrospective measures of height and weight had very high levels of missingness (90%) in the pooled sample in large part because the NHIS data are entirely missing. Even in situations like ours in which the data are missing at random, imputation of variables with such high levels of missingness can result in a large variation of imputed values across imputed data sets, which increases the estimated standard errors in the final analyses. To improve the fit of the imputation model, we included auxiliary variables as predictors that were highly correlated with height and weight at age 25: (1) height and weight at interview and (2) the average height and weight at age 25 of the respondent's birth cohort of the same gender and ethnic/nativity group. This dramatically improved model fit, as illustrated in Table A3. For example, for white men, the R-square value in models predicting weight at age 25 increases from .083 to .514 when current height and weight are added in Model 2, and it increases further to .587 when the cohort measures are added in Model 3.

Table A3. R-square for Imputation Models Predicting Weight at Age 25

	Model 1	Model 2	Model 3
White Men	0.083	0.514	0.587
White Women	0.109	0.468	0.544
FB Hispanic Men	0.076	0.383	0.470
FB Hispanic Women	0.070	0.367	0.475
USB Hispanic Men	0.146	0.518	0.619
USB Hispanic Women	0.135	0.472	0.536

Notes: Sample is 1998-2014 National Health Interview Survey with Mortality Linkages and 1999-2014 National Health and Nutrition Examination Survey with Mortality Linkages. Sample restricted to adults ages 25-84 at interview who were eligible for mortality follow-up. Model 1: Age and year of interview, education, race/ethnicity/nativity, smoking status, mortality status. Model 2: Model 1 predictors and current height and weight. Model 3: Model 2 predictors and average cohort height and weight.

After the CSMI was completed, we detached the NHIS from the NHANES and analyzed the NHIS sample using the MI commands available in Stata.

Section B: Supplementary Analyses Conducted to Test the Same-universe Assumption

We followed Rendall and colleagues' (2013) recommended procedures for detecting violations of the same-universe assumption. Using the pooled, pre-imputation data sets, we estimated three Cox regression models predicting mortality for each ethnicity/nativity and gender group. Model 1 includes all of the predictors observed in both NHIS and NHANES. Model 2 adds an indicator of the sample from which the observation was drawn (NHANES = 1). Finally, Model 3 adds interactions between the sample indicator and all predictors. If Model 3 or Model 2 are improvements over Model 1, this provides evidence of a same-universe violation. To assess model fit, we compared AIC and BIC. Smaller AIC and BIC values indicate better-fitting models, with differences of 10 or greater providing very strong evidence of having a better fit. Results are shown in Table A4.

Table A4. Tests of Same-Universe Assumption

	AIC			BIC		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
White Men	395,915 *	395,917	395,926	396,004 *	396,016	396,114
White Women	446,788	446,787	446,784 *	446,878 *	446,888	446,975
FB Hispanic Men	33,466 *	33,466	33,475	33,538 *	33,546	33,628
FB Hispanic Women	32,266	32,262 *	32,270	32,340 *	32,345	32,427
USB Hispanic Men	21,710 *	21,710	21,718	21,777 *	21,785	21,860
USB Hispanic Women	20,599 *	20,601	20,611	20,669 *	20,679	20,759

Notes: Sample is 1998-2014 National Health Interview Survey with Mortality Linkages and 1999-2014 National Health and Nutrition Examination Survey with Mortality Linkages. Sample restricted to adults ages 25-84 at interview who were eligible for mortality follow-up. *best-fitting model. A lower BIC or AIC value indicates a better-fitting model. Model 1. Predictors only; Model 2. Predictors and survey indicator; Model 3. Predictors, survey indicator and all interactions between it and the predictors.

For 10 out of 12 tests conducted, we detected no violation of the same-universe assumption. The BIC tests (which penalize more heavily than AIC for large numbers of predictors) indicate that Model 1 is the best fitting model for all six demographic groups. The AIC tests support this conclusion for all groups except white women and foreign-born Hispanic women. In the case of white women, the difference in AIC for Model 3 versus Model 1 was moderately-small (4), and only the interactions involving smoking status and year of interview were significant in Model 3. The hazards of smoking 5-9 years for white women was 24% weaker in the NHANES than the NHIS. In the case of foreign-born Hispanic women, the difference in AIC for Model 2 versus Model 1 was moderately-small (4). In Model 2, the sample indicator was significant but none of the interactions were. Overall, the results of these tests do not provide strong evidence of a violation of the same-universe assumption.

As an additional check, we compared the results of our simulations of cohort changes in life expectancy when based on the NHIS to results based on the NHANES data alone. These results are discussed in the paper and shown in Appendix B of the online supplement (Table B1 and Figure B7). Regardless of data source, we found that the mortality advantage relative to whites was maintained for foreign-born Hispanics but lost for U.S.-born Hispanics, although the standard errors and confidence intervals of the estimates are much larger for results based on NHANES alone, as would be expected given NHANES' much smaller sample size.

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Appendix B: Supplemental Tables and Figures

Table B1. Sensitivity of Results To Whether Smoking and Weight Status are Treated as Categorical or Dichotomous

	Men		Women	
	Categorical	Dichotomous	Categorical	Dichotomous
FB Hispanics				
Change in life expectancy due to cohort compositional changes in				
Smoking	0.8 ***	0.5 ***	0.1	0.1
Weight Status	-1.4 ***	-0.7 **	-1.8 ***	-1.0 ***
Smoking and Weight Status	0.0	-0.3	-0.7 *	-0.7 **
USB Hispanics				
Change in life expectancy due to cohort compositional changes in				
Smoking	0.9 ***	0.7 ***	0.4 **	0.4 ***
Weight Status	-3.3 ***	-2.2 ***	-3.1 ***	-2.0 ***
Smoking and Weight Status	-1.5 ***	-1.7 ***	-1.4 **	-1.6 ***
Whites				
Change in life expectancy due to cohort compositional changes in				
Smoking	1.3 ***	1.0 ***	0.2 ***	0.3 ***
Weight Status	-1.5 ***	-0.8 ***	-2.2 ***	-1.3 ***
Smoking and Weight Status	0.5 ***	0.2	-0.8 ***	-1.0 ***

Notes: Sample is 1989-2014 National Health Interview Survey with Mortality Linkages and 1999-2014 National Health and Nutrition Examination Survey with Mortality Linkages. Sample restricted to adults ages 25-84 at interview who were eligible for mortality follow-up. Categorical treatment of smoking: never smoked, <5 years, 5-9 years, and 10+ years as of age 25. Categorical treatment of weight status: BMI <25, 25-29, 30-34, and 35+. Dichotomous treatment of smoking: smoked 5+ years as of age 25 versus <5 years. Dichotomous treatment of weight status: BMI >=30 versus <30. * p<.05; ** p<.01; *** p<.001. FB = foreign-born; USB = U.S.-born.

Table B2. Sensitivity of Results To Whether Mortality Risk is Permitted to Vary or is Constrained to be Equal Across Groups

	Men		Women	
	Varying Risk	Equal Risk	Varying Risk	Equal Risk
FB Hispanics				
Change in life expectancy due to cohort compositional changes in				
Smoking	0.8 ***	1.7 ***	0.1	1.2 ***
Weight Status	-1.4 ***	-1.6 ***	-1.8 ***	-2.2 ***
Smoking and Weight Status	0.0	0.8 ***	-0.7 *	-0.1
USB Hispanics				
Change in life expectancy due to cohort compositional changes in				
Smoking	0.9 ***	1.5 ***	0.4 **	0.6 ***
Weight Status	-3.3 ***	-2.4 ***	-3.1 ***	-2.8 ***
Smoking and Weight Status	-1.5 ***	0.0	-1.4 **	-1.1 ***
Whites				
Change in life expectancy due to cohort compositional changes in				
Smoking	1.3 ***	1.3 ***	0.2 ***	0.2 ***
Weight Status	-1.5 ***	-1.5 ***	-2.2 ***	-2.2 ***
Smoking and Weight Status	0.5 ***	0.4 ***	-0.8 ***	-0.8 ***

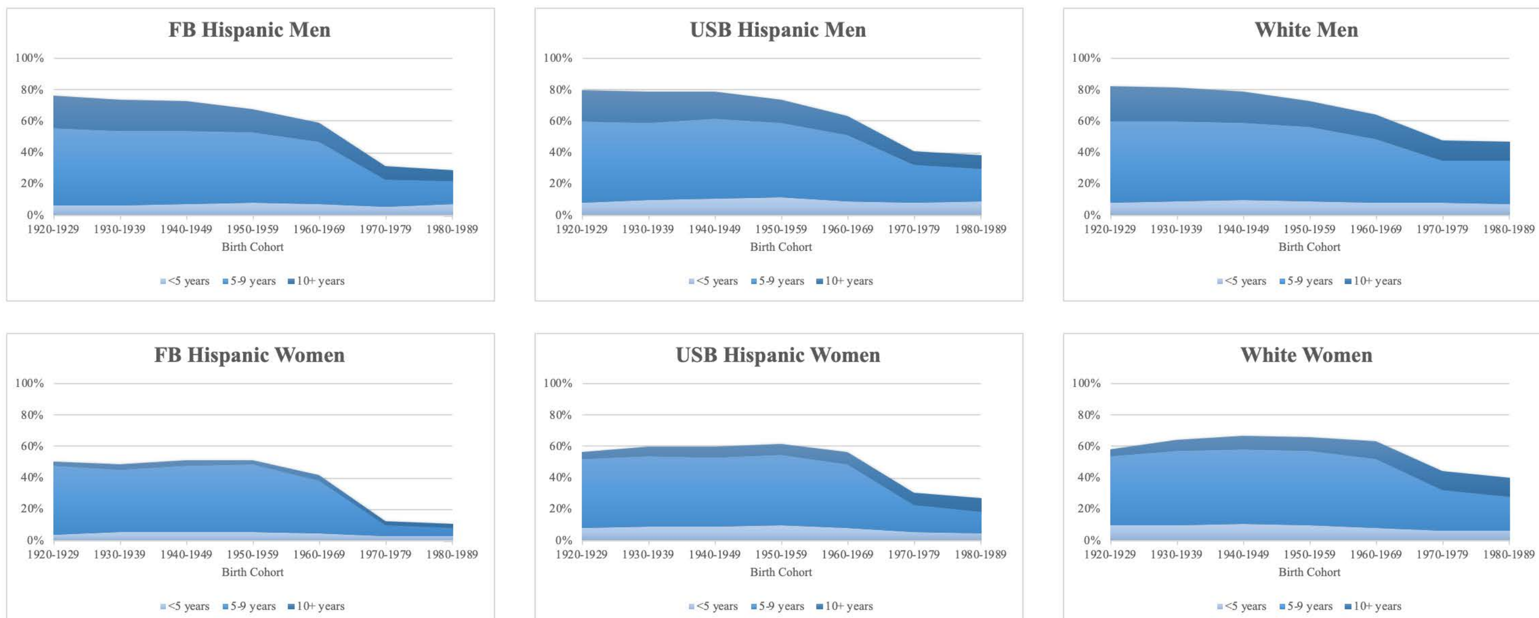
Notes: Sample is 1989-2014 National Health Interview Survey with Mortality Linkages and 1999-2014 National Health and Nutrition Examination Survey with Mortality Linkages. Sample restricted to adults ages 25-84 at interview who were eligible for mortality follow-up. * p<.05; ** p<.01; *** p<.001. FB = foreign-born; USB = U.S.-born.

Table B3. Sensitivity of Results to Data Source

	Men		Women	
	NHIS	NHANES	NHIS	NHANES
FB Hispanics				
Change due to cohort compositional changes in				
Smoking	0.8 ***	0.7	0.1	0.6
Weight Status	-1.4 ***	-0.6	-1.8 ***	-0.5
Smoking and Weight Status	0.0	0.6	-0.7 *	1.0
USB Hispanics				
Change due to cohort compositional changes in				
Smoking	0.9 ***	1.7 *	0.4 **	-0.5
Weight Status	-3.3 ***	-4.4 ***	-3.1 ***	-2.1
Smoking and Weight Status	-1.5 ***	-2.1	-1.4 **	-1.3
Whites				
Change due to cohort compositional changes in				
Smoking	1.3 ***	1.4 ***	0.2 ***	-0.4 *
Weight Status	-1.5 ***	-1.0 ***	-2.2 ***	-1.8 ***
Smoking and Weight Status	0.5 ***	0.7 *	-0.8 ***	-0.8 *

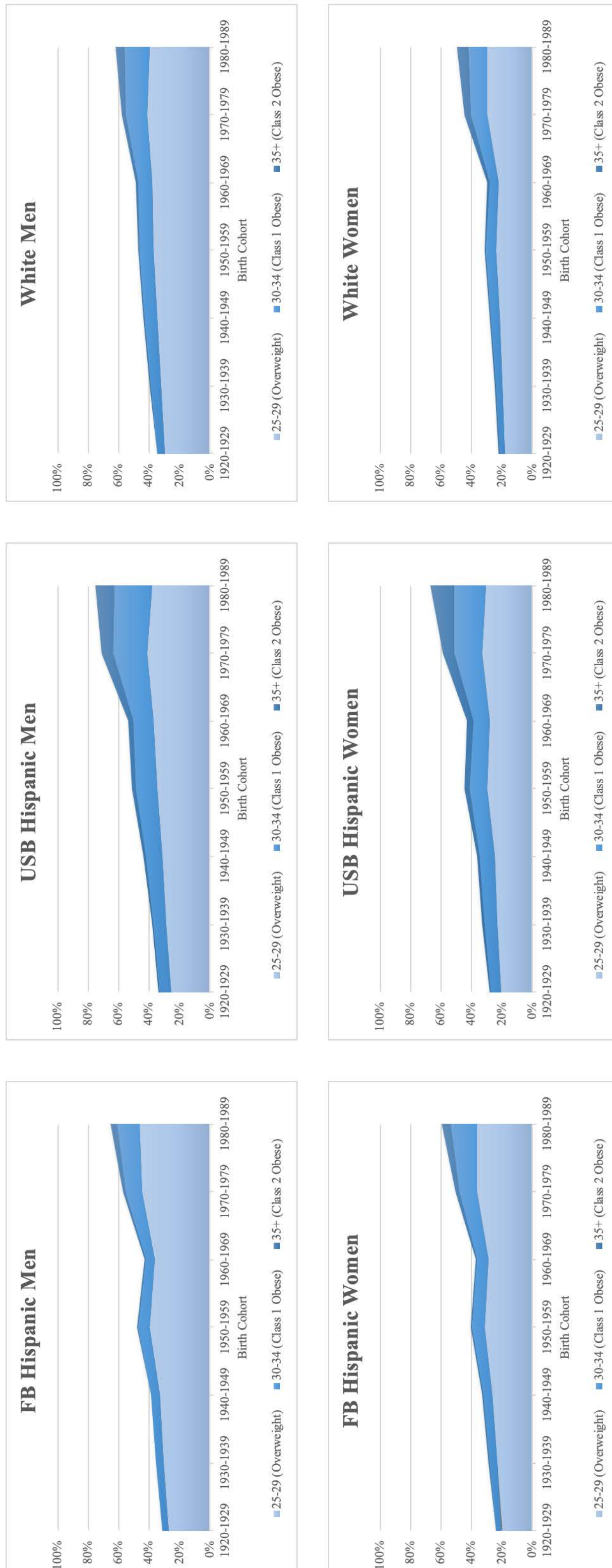
Notes: Sample is 1989-2014 National Health Interview Survey with Mortality Linkages and 1999-2014 National Health and Nutrition Examination Survey with Mortality Linkages. Sample restricted to adults ages 25-84 at interview who were eligible for mortality follow-up. * p<.05; ** p<.01; *** p<.001. FB = foreign-born; USB = U.S.-born.

Figure B1. Estimated Smoking Duration at Age 25 by Birth Cohort, Ethnicity/Nativity, and Gender



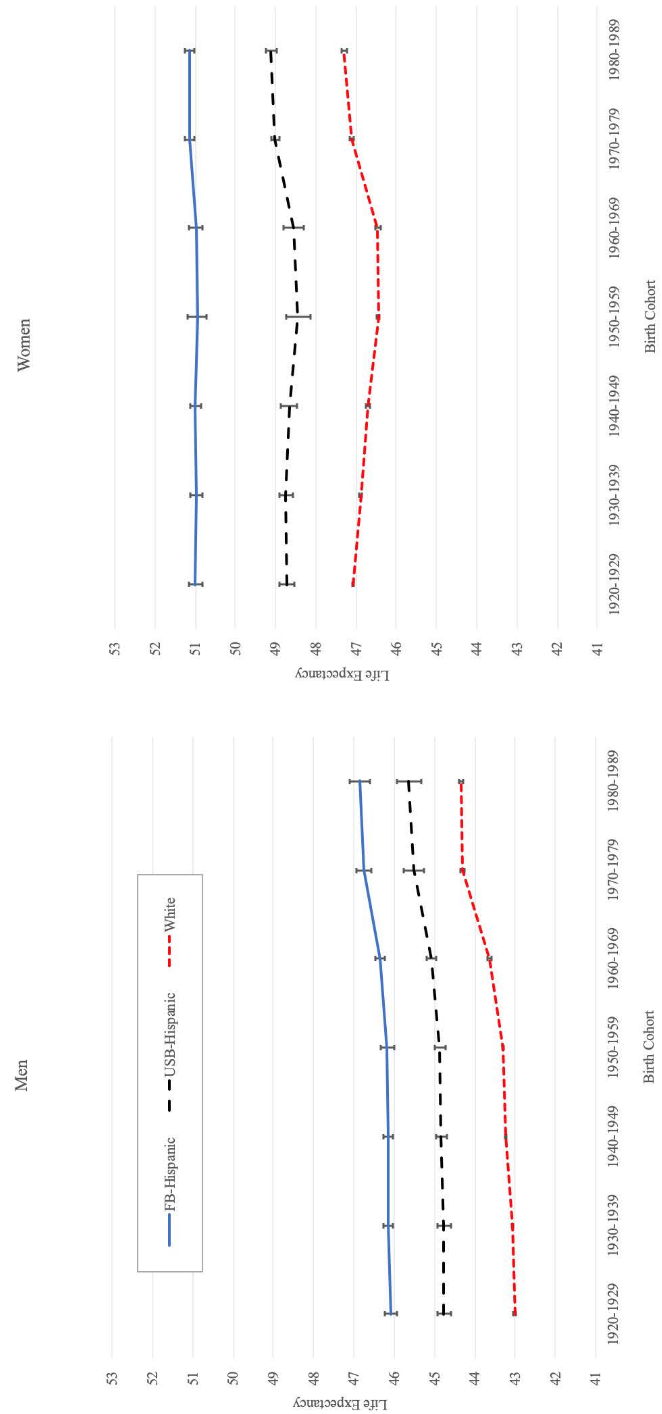
Source: 1989-2014 National Health Interview Survey and 1999-2014 National Health and Nutrition Examination Survey

Figure B2. Estimated Weight Status at Age 25 by Birth Cohort, Ethnicity/Nativity, and Gender



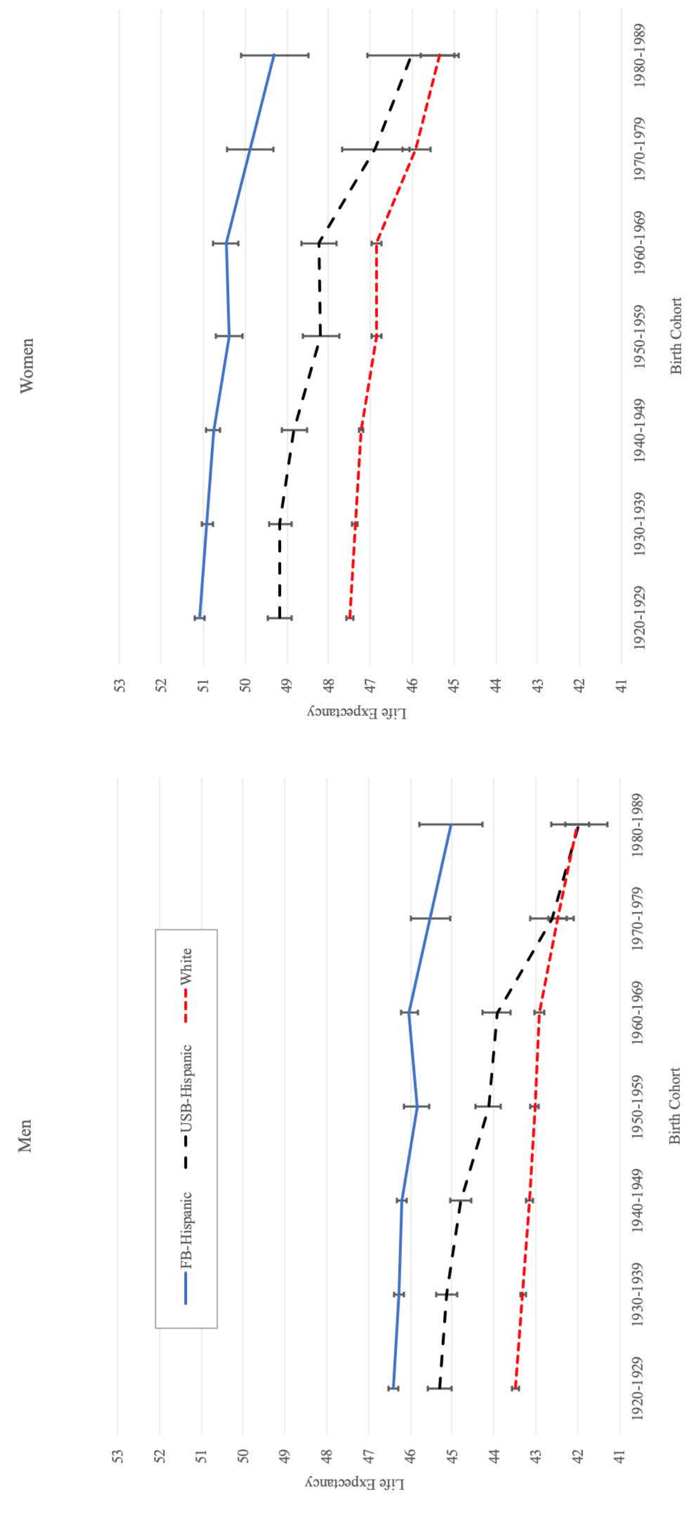
Source: 1989-2014 National Health Interview Survey and 1999-2014 National Health and Nutrition Examination Survey

Figure B3. Simulated Change in Life Expectancy at Age 35
Associated with Cohort Compositional Changes in Smoking at Age 25



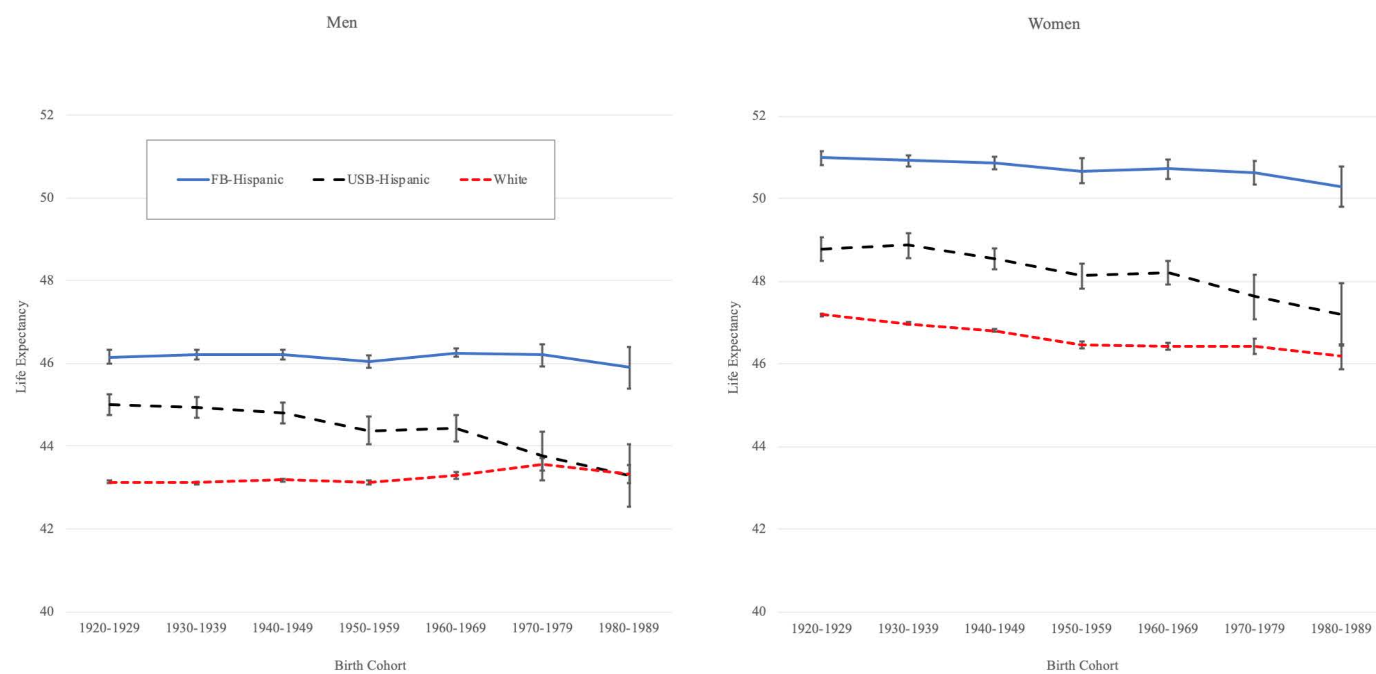
Source: 1989-2014 National Health Interview Survey and 1999-2014 National Health and Nutrition Examination Survey

Figure B4. Simulated Change in Life Expectancy at Age 35
Associated with Cohort Compositional Changes in Weight Status at Age 25



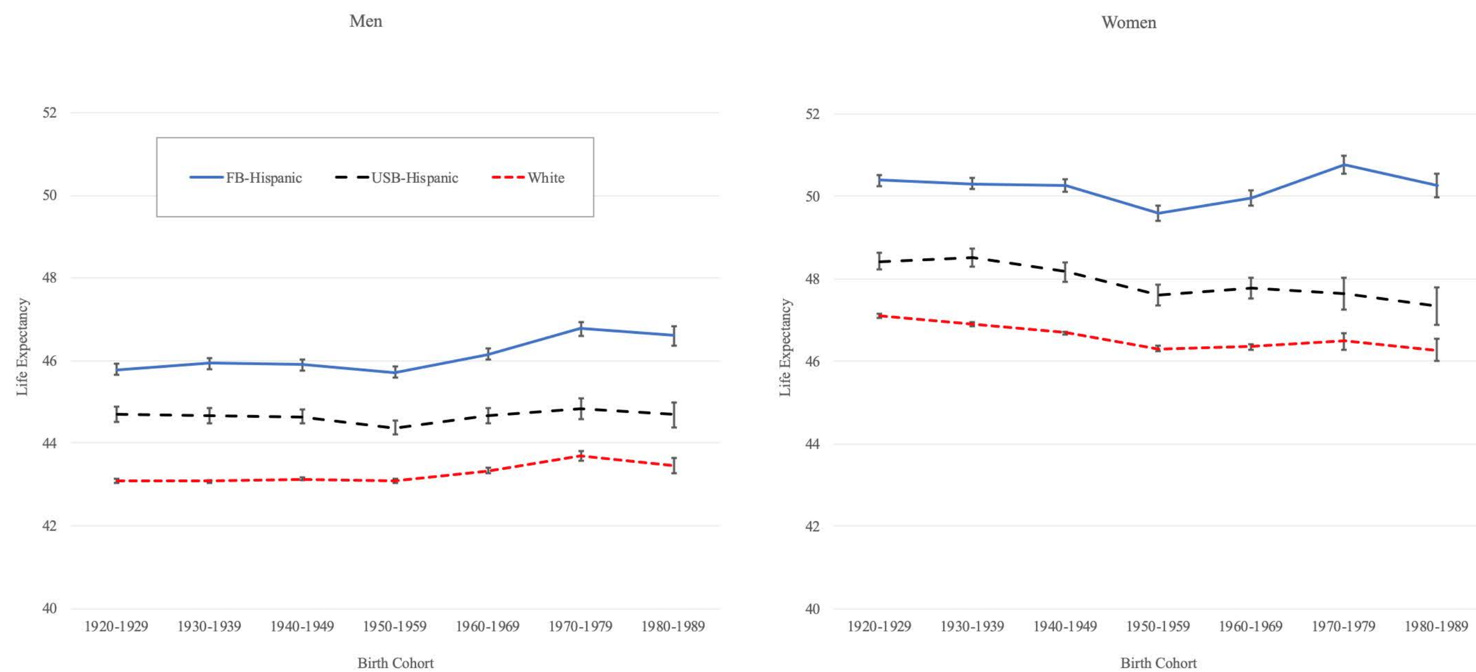
Source: 1989-2014 National Health Interview Survey and 1999-2014 National Health and Nutrition Examination Survey

Figure B5. Simulated Change in Life Expectancy at Age 35
Associated with Cohort Compositional Changes in Smoking and Weight Status At Age 25
When Smoking and Weight Status are Treated as Dichotomous Indicators



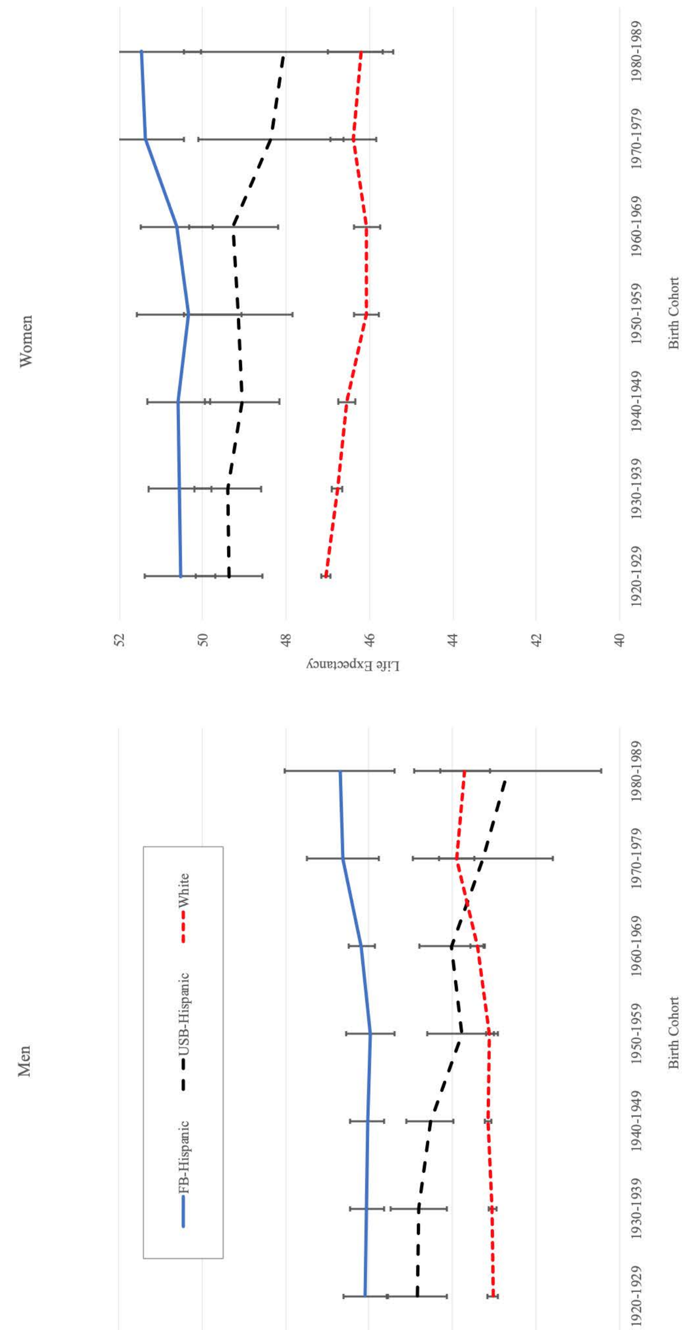
Source: 1989-2014 National Health Interview Survey and 1999-2014 National Health and Nutrition Examination Survey

Figure B6. Simulated Change in Life Expectancy at Age 35
Associated with Cohort Compositional Changes in Smoking and Weight Status At Age 25
When Risks of Smoking and Weight Status are Constrained to be Equal Across Groups



Source: 1989-2014 National Health Interview Survey and 1999-2014 National Health and Nutrition Examination Survey

Figure B7. Simulated Change in Life Expectancy at Age 35
Associated with Cohort Compositional Changes in Smoking and Weight Status At Age 25
When Based on NHANES rather than NHIS



Source: 1989-2014 National Health Interview Survey and 1999-2014 National Health and Nutrition Examination Survey