Working Papers

The Weight of Inequality:
Variation with Industrialization and Wealth

Scott Alan Carson

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Abstract

When other economic measurements are scarce or unreliable, height and the body mass index (BMI) are now well accepted measures for cumulative and current net nutrition. However, as the ratio of weight to height, BMI is the ratio of current to cumulative net nutrition, therefore, does not fully isolate changes in current net nutrition. This study uses weight after controlling for height as a measure for current net nutrition and shows that US black and white weights decreased throughout the late 19th and early 20th centuries, were higher in the South, and for farmers and unskilled workers. Like stature and BMI, 19th century weight was higher in states with greater average wealth and population density and lower in states with greater wealth inequality.

Scott Alan Carson
University of Texas, Permian Basin
4901 East University
USA – Odessa, TX 79762
Carson_S@utpb.edu

The Weight of Inequality: Variation with Industrialization and Wealth

I.   Introduction

When traditional measures for economic welfare are scarce or unavailable, stature and body mass index (BMI) values are now well accepted measures for material well-being (Fogel, 1994; Deaton, 2008; Case and Paxson, 2008; Deaton, 2013). Stature represents the cumulative net difference between calories consumed, less calories required for work and to fend off disease. BMI is weight in kilograms divided by height in meters squared, and changes in BMIs are interpreted as reflecting changes in current net nutrition (Fogel, 1994, pp. 371-373). Nevertheless, because it does not distinguish between muscle, sinew, and bone, BMI remains only a course measure for obesity (Burkhauser and Cawley, 2008, pp. 519-520). In both historic and modern samples, BMI is also the primary means of classifying obesity. However, interpreting BMI variation is more problematic than interpreting stature variation because current BMIs also reflect early life conditions. For example, if an individual is poorly nourished in their youth, they may reach shorter terminal statures (Steckel, 1995), their frames may not fully develop, leading to shorter statures and lower metabolic rates in older ages (Mifflin et al. 1990). If their nutrition improves in later life, they may be more likely to be obese because their weight is distributed over smaller physical dimensions (Herbert et al., 1993, pp. 1438; Carson, 2009a; Carson, 2012a; Sorkin et 1999; Sorkin et al., 1999). On the other hand, if a person receives adequate nutrition during their adolescent years, they reach taller statures, and since their weight is distributed over larger frames, taller statures may be associated with lower BMI values.

There are, however, alternative measures for BMI that reflect current net nutrition, such as weight after controlling for height. Since weight varies more than height with current conditions, weight provides important insight into how current net nutrition varies over time, across ethnicity, and by socioeconomic status (Dawes, 2014, p. 30). Like stature and BMI, weight varies with age, ethnic status, socioeconomic status, residence, and overtime; however, little is known about how 19th century weight varied with wealth inequality, family size, and population density (Carson, 2015b). To isolate how current net nutrition was related to economic conditions, this study uses late 19th and early 20th century weight and height records from multiple state prisons to consider how weight varied by demographic characteristics, socioeconomic status, residence, wealth, and inequality.

It is against this backdrop that this study considers three paths of inquiry into late 19th and early 20th century US black and white weights during economic development. First, how did individual weights vary with wealth accumulation and inequality? Weight increased in wealth at a decreasing rate and was lower in states with greater inequality. Second, how did weights vary with family size? Nineteenth century weights increased with family size, indicating that additional family members increased household wealth, offsetting increases in additional demands on household resources (Becker, 1981, pp. 97 and 102). Third, how did weights vary with population density and urbanization? Weight increased with population density at a decreasing rate, and close proximity to high population density centers was associated with lower weights.

II.   Nineteenth Century U.S. Prison Diets and Weight Data

Weight is an important health measure for current net nutrition that reflects many health conditions related to changes in economic conditions and diets. Weight also reflects the current

net nutrition available to a population. Nineteenth century US diets were relatively plentiful, and annual white diets averaged around 184 pounds of meat, 15 pounds of butter, 13 pounds of lard, and 205 pounds of wheat (Cummings, 1940). Nineteenth century diets and calories varied regionally, and Atack and Bateman (1987) consider 19th century northern white diets and find that Northerners annually consumed about 200 pounds of meat, 770 pounds of fluid milk, butter, and cheese, and 13.5 bushels of grain. Shergold (1982, pp. 185-195), Hilliard, (1972, pp. 135 and 166), and Comer (2000, p. 1315) find that Northeastern diets were high in dairy products, grains, and breads. Southern diets were more diverse than northern diets, and meat was more readily available in the South (Hilliard, 1972, pp. 112-140). Part of the Southern nutrition advantage was related to greater agricultural productivity (Fogel and Engerman, 1974, p. 193); however, after emancipation, Southern food production decreased (Ransom and Sutch, 1977, pp. 151-156). In sum, late 19th century US nutrition varied regionally, and how net nutrition varied with family size, wealth, and urbanization reflects nutritional conditions during early economic development.

The two most common sources of historical weight and height data are military and prison records. Military records represent conditions among the upper class, while prison records represent conditions among the working class (Sokoloff and Vilaflour, 1982). One potential problem associated with military weights is a minimum stature requirement for service that omits enlistees below a given stature, typically 64 inches. This stature truncation may influence military weights because weight is related to height and by truncating recruits with shorter statures means that only taller individuals with lower BMIs remain in military samples (Herbert et al., 1993, p. 1438; Carson, 2009a; Carson, 2012a). Prisoners are an alternative to soldiers; however, when used as a measure for current net nutrition, prison data have their own

disadvantages. For example, it is not clear which social class prisoners represent because law enforcement officials may have incarcerated many of the materially poorest individuals who did not reach their genetically predetermined statures.[1] On the other hand, if law enforcement officials inferred guilt from larger physical size, prison enumerators may have incarcerated many of the tallest, most physically fit individuals involved in crime. However, there is no systematic relationship between heights and the various crimes for which individuals were incarcerated (Carson, 2005, p. 411; Carson, 2007, p. 44).

Prison enumerators were thorough when recording inmate complexions, and white inmate complexions were recorded as fair, light, medium, and dark. Black inmate complexions were recorded as black, light-black, dark-black, and various shades mulatto. Throughout this manuscript, individuals recorded as mulattos in the original prison registries are referred to as mixed race here. Although these mixed race individuals shared genetic characteristics with both blacks and whites, they were treated as blacks in the 19th century US, and when appropriate, are grouped here with blacks. Enumerators recorded various occupation categories which are classified here as white-collar, skilled, farmers, unskilled, and workers with no listed occupations. Highly skilled workers, bankers, and merchants are classified as white collar workers; blacksmiths, carpenters, and craft workers are classified as skilled workers; farmers, dairy workers, and ranchers are classified as farmers. Laborers and miners are classified as unskilled workers. Prison enumerators typically did not distinguish between farm and common laborers; however, the distinction is important because urban workers encountered less favorable

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[1] There has been considerable attention given to potential biases caused from using military and prison records to assess the antebellum and early industrial growth paradox. However, the critique has not been well supported. http://aez.econ.northwestern.edu/zimran_height_selection.pdf

biological conditions, while farm laborers encountered better net nutritional conditions, which likely understates the biological benefits of being a farm laborer and overstates the biological advantages that accrued to common laborers (Carson, 2013; Carson, 2015a). Between 1840 and 1920, prison guards typically recorded an individual's age, the date of entry, nativity, complexion, stature, weight, pre-incarceration occupation, and crime. Because wealth, inequality, and family size were only recorded in the 1860 and 1870 censuses, the prison data are restricted to observations between 1855 and 1874.

Three existing studies that shed light on historical weights are Komlos (1987), Komlos and Coclanis (1995), and Carson (2015b). For West Point cadets, Komlos (1987) demonstrates that 19th century weights decreased, which was experienced across the US and was experienced by farmers and unskilled workers. Coclanis and Komlos (1995, p. 104) support this finding by using late 19th and early 20th century student records at the Citadel to show that weights decreased throughout the late 19th century. Carson (2015b) shows that US weights decreased throughout the 19th century, were greater in the South, and were higher for workers in agricultural occupations. Historical weight studies have otherwise received little attention. Nothing is known, however, about how 19th century black and white weight varied by wealth inequality, and population density.

Table 1, Nineteenth Century Black and White Demographics and Socioeconomic Status

	Blacks		Whites	
	N	Percent	N	Percent
Ages				
Teens	1,062	23.01	871	19.61
20s	2,604	56.41	2,469	55.58
30s	575	12.46	710	15.98
40s	236	5.11	250	5.63
50s	113	2.45	116	2.61
60s	24	.52	20	.45
70s	2	.04	6	.14
Birth Decade				
1800s	9	.19	28	.63
1810s	93	2.01	113	2.54
1820s	168	3.64	216	4.86
1830s	437	9.47	614	13.82
1840s	1,686	36.43	1,763	39.69
1850s	2,188	47.40	1,706	38.41
1860s	35	.76	2	.05
Observation Decade				
1860s	980	21.23	1,307	29.42
1870s	3,636	78.77	3,135	70.58
Occupations				
White-Collar	55	1.19	115	2.59
Skilled	219	4.74	793	17.65
Farmers	13	.28	18	.41
Unskilled	2,452	53.12	2,299	51.76
No Occupation	1,877	40.66	1,217	27.40
Nativity				
Northeast	157	3.40	870	19.59
Middle Atlantic	177	3.83	509	11.46
Great Lakes	58	1.26	352	7.92
Southeast	3,845	83.20	2,451	55.18
Southwest	300	6.50	138	3.11
Far West	2	.04	2	.05
Residence				
Kentucky	1,530	33.15	1,991	44.82

Oregon	3	.06	30	.68
Philadelphia	273	5.91	1,078	24.27
Tennessee	1,825	39.54	818	18.42
Texas	985	21.34	525	11.82
	4,616	100.00	4,442	100.00

Source: Date used to study anthropometrics is a subset of a much larger 19th century prison sample. All available records from American state repositories have been acquired and entered into a master file. These records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, New Mexico, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Utah and Washington.
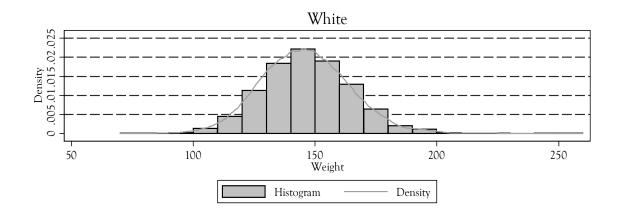
Notes: Prisons used in this study are restricted to states that recorded weight that can be linked to average state values.

Blacks were incarcerated at younger ages, and whites were incarcerated and older ages (Hirschi and Gottfredson, 1983; Carson, 2009a). Whites made up a larger portion of the early 19th century prison population, but with emancipation and passage of the 13th Amendment, African-Americans made up a larger portion of the prison population. Before emancipation, slave masters had claims on slave labor, but incarceration prevented slave-owners from earning returns on their slave property. Early Southern laws, therefore, evolved to allow owners to punish their slaves on their plantations while slaves worked to pay the social costs of their crimes (Wahl, 1996; Wahl 1997). However, with emancipation, slave owners no longer had claims on slave labor, and blacks who broke the law were more likely to be incarcerated after emancipation. There were more whites in US prisoners than blacks; however, blacks are overrepresented in the prison population relative to whites in the general population.

Figure 1, Late 19th and Early 20th Century Black and White Male Weight

Black

White

Source: See Table 1.

A population's weight distribution provides insight on its current net nutrition. If a weight distribution is negatively skewed, there is a disproportionate number of underweight individuals, Figure 1 presents weight kernel density estimates and illustrates that weight distributions were nearly symmetric. For current net nutrition, black and white men were neither starved nor did they live in choleric abundance. Average black weight was 151.20 pounds, and average black height was 66.67 inches. Average white weight was 145.95 pounds, and white average height was 67.52 inches, indicating that blacks were short and heavy, while whites were tall and thin.

III.   Nineteenth Century Black and White Weight Variation

We now test how heights, demographics, and material conditions were associated with late 19th and early 20th century US weights. To start, weights are regressed on height, complexion, age, occupation, wealth, inequality, population density, nativity, birth decades, and family size.

$$
\begin{aligned}
Weight_i &= \alpha \ + \beta_I\, Inch_i + \sum_{p=1}^{2} \beta_p Complexion_i + \sum_{a=1}^{15} \beta_a\, Age_i + \beta_l\, Farmers\ \&\ Laborers \\
&+ \beta_{TW}\, Total\, Wealth_i + \beta_{TW^2}\, Total\, Wealth_i^2 + \beta_G\, Wealth\, Gini_i + \beta_{PD}\, Population\, Density_i \\
&+ \beta_{PD^2}\, Population\, Density_i^2 + \sum_{n=1}^{6} \beta_n Nativity_i + \sum_{b=1}^{5} \beta_b\, Birth\, Decade_i \\
&+ \beta_{FS}\, Family\, Size_i + \beta_{FS^2}^2\, Family\, Size_i^{\,2} + \varepsilon_i
\end{aligned}
$$

Weight in pounds is regressed on height in inches to account for the relationship between cumulative net nutrition. Dark and light black complexion dummy variables are included to account for how weight varied with complexion. Youth age dummy variables are included for ages 14 through 22; adult age dummies are included in ten year age intervals from age 30 through their 70s. To account for how height varied with socioeconomic status, an occupation dummy variable is included for farmers and unskilled occupations. State level wealth and Gini coefficients are included to account for the relationship between weight, wealth, and inequality. Wealth and inequality may also be related to urbanization, and state population density variables are included to account for the relationship between weight and urbanization. To assess how weight varied throughout the 19th century, birth decade dummy variables are included in ten year intervals from 1800 through 1850. Family size and family size squared variables are included to account for the relationship between weight and family size.

Table 2's model 1 includes black and white BMIs to account for how BMIs varied with observable characteristics. Model 2 demonstrates how black and white weight varied with the same characteristics. To illustrate how the percentage change in weight varied with observable characteristics, Model 3 presents the same model with the natural log of weight as the dependent variable. Model 4 accounts for how black weight varied in levels with demographic, socio-economic, and wealth characteristics, while Model 5 does the same for whites. Models 6 and 7 consider the weight relationship between youths and adults.

Table 2, Nineteenth Century Weight by Demographics, Socioeconomic Status, Wealth, and Inequality

	BMI	Total Weight	Total, ln(weight)	Black Weights	White Weights	Youth Weights	Adult Weights
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Intercept	34.39***	-81.91***	3.43***	-73.74***	-89.80***	-31.31	-91.88***
Height							
Inches	-.177***	3.37***	.023***	3.38***	3.38***	3.20***	3.45***
Ethnicity							
White	Reference	Reference	Reference			Reference	Reference
Black	1.23***	8.07***	.054***	Reference		5.81***	9.30***
Mixed-race	.861***	5.64**	.037***	-1.70		5.12***	5.97***
Ages							
14	-3.16***	-17.67***	-.142***	-19.25***	-14.21***	-17.03***	
15	-3.10***	-18.33***	-.143***	-18.91***	-17.28***	-17.65***	
16	-2.31***	-13.94***	-.105***	-16.08***	-10.84***	-13.09***	
17	-1.44***	-8.84***	-.064***	-9.36***	-8.15***	-7.89***	
18	-1.30***	-8.10***	-.056***	-9.90***	-6.10***	-7.05***	
19	-.650***	-4.27***	-.028***	-5.45***	-3.26***	-3.14***	
20s	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30s	.222***	1.45**	.009**	1.04	1.75**		1.25*
40s	.495***	3.27**	.020***	4.76***	1.65		3.12***
50s	.363	1.99	.013	3.58	.263		1.97
Occupations							
Non-Farmers	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Farmers and Laborers	.168***	1.06**	.008***	.950	.892	.869	.996

Wealth							
Total Wealth	-.0002	-.001	-1^{-5}	-.005***	.001	-.003	-.001
Total Wealth^2	1.76^{-7}***	1.14^{-6}***	7.64^{-9}***	7.12^{-7}**	1.02^{-6}***	6.68^{-7}	1.27^{-6}***
Gini Coefficient	-.126***	-.866***	-.006***	-.108	-.931***	-.727**	-.949***
Population Density							
Population Density	.035***	.231***	.002**	.398***	.166	.365	.231***
Population Density^2	-.001***	-.004***	-2.8^{-5}***	-.005***	-.004***	-.006***	-.004***
Nativity							
Northeast	-.306	-1.60	-.012	-6.71**	-.609	1.04	-2.57
Middle Atlantic	-.224***	-1.36**	-.009***	-2.56**	-.434	-1.16	-1.37*
Plains	-.117	-.850	-.004	1.22	-1.61	.550	-1.48
Great Lakes	-.019	.187	-1.0^{-4}	-2.34	1.01	.900	-.304
Southeast	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Southwest	-.210*	-1.35	-.010*	-.551	-2.92*	-1.34	-1.95*
Far West	.987	5.99	.046	9.85***	5.21	4.72	2.38
Birth Decade							
1800s	-.527	-3.88	-.024	-8.93***	-1.96		-3.96
1810s	.033	.537	.002	-2.81	3.97		.139
1820s	-.215	-1.42	-.010	-3.00	.057		-1.67
1830s	-.017	-.058	-5.0^{-4}	-.983	.710	2.94	-.324
1840s	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1850s	-.234***	-1.41***	-.010***	-2.03***	-.711	-.671	-1.02**
Family Size							
Family Size	1.38	9.39**	.060*	1.06	11.04***	1.44	10.81***
Family Size^2	.012	.084**	.001***	.190***	.039	.151	.083*
N	9,058	9,058	9,058	4,616	4,442	3,265	5,793
R^2	.1958	.4032	.4177	.4150	.3754	.4490	.3189

Source: See Table 1.

Three paths of inquiry are considered when examining late 19th and early 20th century black and white weights. First, weight is related to wealth through absolute wealth holdings and relative wealth inequality. Across the 19th century US, weights increased in average state wealth holdings at a decreasing rate and was inversely related to wealth inequality, indicating that better current net nutrition improved at a decreasing rate with wealth. Moreover, weight was inversely related to inequality, which limited access to nutrition among poor individuals (Table 2). Through the absolute wealth channel, weight increases in wealth at a decreasing rate because the last dollar spent on health and nutrition by a poor person has a greater impact on weight than the last dollar spent on nutrition by a wealthy person (Steckel, 1983). On the other hand, through the wealth inequality pathway, weight decreases with wealth inequality because greater inequality forecloses poorer individuals from access to nutrition. These inequality results are important because in combination with previous findings, height, BMI, and weight increased in wealth at a decreasing rate and were inversely related to inequality (Steckel, 1983; Carson, 2009a; Carson, 2010; Carson, 2013).

Second, 19th century weights were positively related with average household size, and additional family members increased labor specialization and agricultural productivity, off-setting increased demands on household resources associated with additional family members (Table 2; Edwards and Grossman, 1978, pp. 38-39; Atack and Bateman, 1987, p. 56, Becker, 1981, pp. 97 and 102). To measure the relationship between weight and family size, individual weight is ideally linked to an individual's own family size. However, these linkages for the late 19th century are not available; therefore, average family size by state is used in their stead. Average state family size from census records reflects economic and social needs, and given local agricultural and economic conditions, the effect of state's average family size reflects the

needs of local labor needs.[2] Moreover, defining a family is a cultural as well as a socioeconomic institution, and households historically chose the number of members needed based on internal labor needs. Given this 19th century rural-urban difference, rural family needs were different from urban family size needs. The relationship between weight and family size may also have worked in reverse direction. Weight measures current net nutrition and stronger individuals may have had greater weight and were better able to support larger families. In sum, weight was positively and independently related to family size, indicating that greater resource demands placed on household net nutrition were offset by greater labor productivity associated with additional family members.

Third, weight is also related to state population density, and because greater population density may have led to dietary stress unique to urban areas, isolating the absolute weight-wealth relationship requires accounting for urbanization (Steckel, 1995; Carson, 2010). Weights increased at a decreasing rate in population density, and maximum weight was reached at 17.50 persons per square mile, which is approximately equal to the population density of Alabama and Mississippi. Part of the weight-density population relationship may be associated with the effects of being in close proximity to water transportation systems, which increased exposure to disease. Close proximity to trade routes also reflects exposure to trade, migration, and markets, which increased the relative price of food in urban centers (Komlos, 1987).

Other patterns are consistent with expectations. Nineteenth century weights were related to ethnic status, and across the distribution, dark and light African-American complexions had

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[2] Because individual household size is not available, this explanation relies on the survivorship principle that posits that if a particularly plant size is efficient in the market place, all plant sizes in the market place will adapt this technology and converge on this plant size (Stigler, 1958).

greater weights than whites. Much has been written about the 19th century 'mulatto stature advantage' (Steckel, 1979; Margo and Steckel, 1982; Margo and Steckel, 1992; Bodenhorn, 2002; Carson, 2008; Carson, 2009c), and whites and light-complexioned blacks had taller statures than darker complexioned blacks. However, for both BMIs and weight, darker complexioned blacks had heavier weights than fairer complexioned whites and lighter complexioned African-Americans (Carson, 2012b; Carson, 2015c). Part of heavier black weights is biological, and blacks have greater protein in their muscle tissue, and for the same tissue volume, muscle is heavier than fat (Wagner and Heyward, 2000).[3]

Nineteenth century weights were positively related to height. For both blacks and whites, each additional inch in height was associated with 3.50 pounds or two percent heavier weight, and the weight-height relationship is robust across the weight distribution. After controlling for height, dark and light complexioned black weights were five and three percent greater than white weights. Weight variation was sensitive to socioeconomic status, and 19th century farmers and unskilled workers were taller and had greater BMIs across the stature and BMI distributions than workers in other occupations (Carson, 2015b; Carson 2015d).

Diets, disease climates, and work intensity varied with residence and after controlling for wealth and inequality, weights in the rural South were greater than other regions within the US. Individuals from Southern states had greater weights than elsewhere within the US, due in part, to greater agricultural productivity. Diets in the South were, therefore, rich in calories and animal proteins, indicating that after work requirements are accounted for, weights in the South provided more net calories than elsewhere within the US (Hilliard, 1972). The South was also

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[3] This post-obesity epidemic complexion pattern may have changed if whites put on more weight than blacks in recent decades.

more rural than other regions within the US, and heavier Southern weight indicates that rural Southern current net nutrition offset calories required for work and to fend off disease. In the late 19th and early 20th centuries, the Northeast was the most industrialized, and Northeastern weights were lower than elsewhere within the US. In sum, weight was related with 19th century demographics, residence, and socioeconomic conditions, and throughout life, statures, BMIs, and weight increased in wealth and population densities at decreasing rates and was inversely related with inequality.

IV.   Black and White Demographics, Occupations, and Weights: A Sensitivity Analysis

Collective and joint relationships between weight, demographics, socioeconomic status, wealth, and inequality are also noteworthy. Regression coefficients account for how individual characteristics are related to individual characteristics. They do not, however, account for how a group of variables are related to a dependent variable. For example, a single occupation coefficient—such as farming—is related to weight, but its coefficient does not represent how weight collectively varied with occupations. Sensitivity analysis accounts for how a dependent variable responds to collective effects and provides a measure for how the response variable changes with a set of characteristics. Unrestricted and restricted models for 19th century weight are presented in Table 3. Model 1 includes all available characteristics, such as height, complexion, age, and period received (Leamer, 1983; Leamer 2010; Angrist and Pishke, 2010). Subsequent models exclude characteristics to account for the magnitude for how weight varied with collective effects.

Table 3, Sensitivity Analysis for Weight by Demographics, Socioeconomic Status, Wealth, and Inequality

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
	Total	Height Omitted	Race Omitted	Age Omitted	Occupation Omitted	Wealth Omitted	Population Omitted	Nativity Omitted	Birth Period Omitted	Family Size Omitted
Intercept	-81.91***	136.35***	-62.36***	-106.3***	-83.51***	-75.56***	-107.37***	-81.81***	-83.89***	-91.20
Height										
Inch	3.37***		3.11***	3.68***	3.37***	3.37***	3.38***	3.37***	3.38***	3.36***
Ethnicity										
Black	8.07***	4.26***		8.20***	8.13***	8.02***	7.99***	8.12***	8.05***	8.04***
Mixed-race	5.64***	3.69***		5.60***	5.64***	5.59***	5.22***	5.66***	5.55***	5.61***
White	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Ages										
14	-17.67***	-31.80***	-17.66***		-17.61***	-17.64***	-17.17***	-17.70***	-17.99***	-17.66***
15	-18.33***	-29.78***	-18.18***		-18.30***	-18.28***	-17.79***	-18.38***	-18.80***	-18.38***
16	-13.94***	-22.10***	-14.02***		-13.89***	-13.93***	-13.37***	-13.87***	-14.65***	-13.93***
17	-8.84***	-13.65***	-9.22***		-8.78***	-8.82***	-8.31***	-8.82***	-9.42***	-8.86***
18	-8.10***	-10.85***	-8.35***		-8.07***	-8.06***	-7.59***	-8.09***	-8.65***	-8.07***
19	-4.27***	-5.17***	-4.66***		-4.23***	-4.23***	-3.92***	-4.25***	-4.78***	-4.28***
22-29	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
30s	1.45**	1.28*	1.49**		1.41**	1.34**	.462	1.40**	1.99***	1.53**
40s	3.27***	2.70*	3.85***		3.25**	3.10***	1.45	3.26**	3.18***	3.42***
50s	1.99	-.535	2.28		2.02	1.80	-.529	1.96	2.27*	2.17
Occupation										
Non-	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference

Agricultural	e		e	e		e		e	e	e
Farmer & Laborer	1.06**	1.70***	2.10***	.553		1.01*	2.11***	1.13**	1.12**	1.53***
Wealth										
Total Wealth	-.001	-.001	-.002	-.002	-.001		-.002	-.001	-.001	-.003***
Total Wealth	1.14^{-6}***	1.34^{-6}***	8.83^{-7}***	1.0^{-6}	1.15^{-6}***		-5.46^{-7}	1.14^{-6}***	1.18^{-6}***	8.23^{-7}***
Gini Coefficient	-.866***	-.851**	-.826**	-.796**	-.812***		1.19***	-.910***	-.889***	.206
Population										
Population Density	.231***	.001	.229***	.171***	.229***	.199***		.260***	.235***	.136***
Population Density^2	-.004***	-.003***	-.004***	-.003***	-.004***	-.003***		-.005***	-.004***	-.003***
Nativity										
Northeast	-1.60	-3.95*	-3.32**	-1.18	-1.66	-1.49	-1.78		-1.59	-1.52
Middle Atlantic	-1.36**	-3.24***	-2.51***	-.838	-1.46**	-1.28**	-1.30**		-1.30**	-1.26**
Plains	-.850	-1.94**	-2.43**	-.829	-.904	-.830	-.850		-.851	-.800
Great Lakes	.187	-1.85*	-2.77***	.343	.127	.229	.918		.245	.332
Southeast	Reference	Reference	Reference	Reference	Reference	Reference	Reference		Reference	Reference
Southwest	-1.35	.155	-1.32	-2.37***	-1.31	-1.40*	-2.17***		-1.44*	-1.58*
Far West	5.99	2.43	6.74	1.17	5.65	8.84**	16.18***		6.47	11.33***
Birth Decade										
1800s	-3.88	-7.14***	-5.61**	-2.55	-4.06	-3.77	-2.86	-3.91		-3.98
1810s	.537	2.93	.387	3.24***	.417	.831	3.48*	.527		.462
1820s	-1.42	-.648	-2.01	1.91**	-1.46	-1.28	.713	-1.40		-1.58
1830s	-.058	.074	-.290	2.04***	-.099	.099	1.25*	-.022		-.127

1840s	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference		Reference
1850s	-1.41***	-2.06***	-1.08***	-4.71***	-1.43***	-1.45***	-2.21***	-1.41***		-1.39***
Family Size										
Family Size	9.39**	12.09**	9.52**	9.42**	9.06**	-1.50*	-8.38**	9.66**	9.71**	
Family Size²	.084***	-.051	.062	.089**	.108**	.106***	-.002	.090***	.081**	
N	9,058	9,058	9,058	9,058	9,058	9,058	9,058	9,058	9,058	9,058
R²	.4032	.1915	.3692	.3674	.4030	.4020	.3961	.4026	.4021	.4021

Source: See Table 1.

Two important but possibly related variables associated with weight variation are height and age. During young growing ages when stature growth occurs, height and age are highly related. Sensitivity analysis helps parse the collective effects of height and age relationship with weight. First, when height is restricted in Model 2, the relationship between weight, complexion, age, and occupations vary considerably. A joint hypothesis test between weight and height also demonstrates that height is significantly related to height, $F(1, 141,361)=29,250.76$, $p=.001$. When subsequent subsets of observable characteristics are omitted in Models 3 through 7, there is little variation between the relationships with weight characteristics, representing a causal effect between weight and height (Miller, 2005, pp. 37-38). Second, a joint hypothesis test on age demonstrates that weight is significantly related with age, $F(14, 141,361)=690.55$, $p=0000$, but when age is omitted, there is less coefficient variation than when height is omitted; therefore, the relationship between weight and height was significant in weight variation. Age coefficients do not vary when weight is omitted, indicating that height but not age had the greatest relationship with weight.

IV.   Assessing the Magnitude of Weight Variation with Collective Effects

Weight values and other health measurements are sensitive to two general characteristics: choice and non-choice characteristics. For example, age and race are two characteristics over which individuals have no control; however, occupation and residence are two variables that individuals exercised considerable discretion. F-statistics test the statistical significance of a restricted set of variables, and observable demographic, occupations, and residence were jointly related with 19th century weight variation. F-statistics do not, however, account for the

magnitude or relative importance that each restricted set of variables had with weight changes. To account for restricted variables' magnitude with weight variation, a percentage change in the restricted model sum of squared regression (SSR$_R$) relative to the unrestricted sum of squared regression (SSR$_U$) is reported for each of the restricted variable subsets reported in Table 3.

$$\%\mathit{\Delta SSR} = \frac{SSR_R - SSR_U}{SSR_U} = \frac{R_R^2 - R_U^2}{R_U^2} = \%\mathit{\Delta R}^2$$

Within the set of non-choice variables, height had the greatest relationship on the percentage change with weight variation. The percent change in weight variation when height is omitted decreases by 52.5 percent; age accounts for an 8.9 percent decrease, and race accounts for an 8.4 percent decrease. Within the set of choice variables, population density accounts for a 1.8 percent decrease in weight variation; nativity accounts for a 1.5 percent decrease in weight variation, while family size, wealth, and occupations only account for .27, .25, and .05 percent decreases in weight variation, respectively. Therefore, among non-choice characteristics, height had the greatest explanatory power with weight variation. Among choice characteristics, population density accounts for the greatest explanatory ability, and non-choice characteristics had the greatest explanatory power in 19th century weight variation.

V.   Conclusion

When traditional measures for economic well-being are scarce or unreliable, statures and BMIs are now well accepted measures for material welfare. However, because BMI represents the ratio of net current to net cumulative nutrition, it limits BMI's application as a measurement for net current nutrition. BMIs increase when weight in the numerator increases current net nutrition increases but BMI increases when height in the numerator is low, and these two measures represent opposing factors in BMI variation. This study demonstrates that 19th black

and white weights increased at a decreasing rate in average state wealth and was lower in states

that had greater wealth inequality. Individual weights were heavier in states that had larger

family sizes, indicating that larger family size was a biological net benefit that offset additional

demands placed on household resources. As with stature and BMI, individual weight was related

to population density, and an individual's weight increased in population density through 17.5

persons per square mile and decreased thereafter. Because urban diets were compromised with

the separation of food consumption from food production, farmers were in close proximity to

diets high in complex carbohydrates and animal proteins, whereas white collar and skilled

workers in urban areas had diets with inferior net nutrition. The majority of historical weight

variation was associated with combined effects of height and age, and weight differences vary

considerably when uncontrollable height, age, and race are excluded. Therefore, 19th century

weights were related to complexion, socioeconomics, and residential characteristics, and weight

varied the most with factors an individual had little control.

References

Angrist, J. and J. S. Pischke. 2010. The credibility revolution in empirical economics: how better research design is taking the con out of econometrics. *Journal of Economic Perspectives* 24, pp. 3-30.

Atack, J., and Bateman, F., (1987). *To Their Own Soil: Agriculture in the Antebellum North.* Ames, Iowa: Iowa State University Press.

Becker, G. (1981). *A Treatise on the Family*. Cambridge: Harvard University Press.

Burkhauser Richard and John Cawley. (2008). "Beyond BMI: The Value of More Accurate Measures of Fatness and Obesity in Social Science Research." *Economics and Human Biology,* 27, pp. 519-529.

Carson, Scott Alan. (2005) "The Biological Standard of Living in 19th-Century   Mexico and in the American West," *Economics and Human Biology,* Volume 3(3), pp. 405-419.

Carson, Scott Alan. (2007). "Mexican Body Mass Index Values in the 19th Century American West," *Economics and Human Biology,* Volume, 5(1), pp. 37-47.

Carson, Scott A. (2008). The Effect of Geography and Vitamin D on African-American Stature in the Nineteenth Century: Evidence from Prison Records. *Journal of Economic History.* 68(3), pp. 812-831.

Carson, Scott A. (2009a) "Racial Differences in Body-Mass Indices of Men Imprisoned in 19th Century Texas" *Economics and Human Biology* 7, pp. 121-127.

Carson, Scott Alan, (2009b) "Health, Wealth and Inequality: a Contribution to the Debate about the relationship between Inequality and Health," 42(4), *Historical Methods*. pp. 43-56.

Carson, Scott Alan, (2009c) "Geography, Insolation and Vitamin D in 19th Century US

African-American and White Statures," 46(1), *Explorations in Economic History.* pp. 149-159.

Carson, Scott Alan. (2010), "Wealth, Inequality, and Insolation Effects across the 19th Century White US Stature Distribution," *Journal Homo of Comparative Human Biology,* 61, pp. 467-478.

Carson, Scott Alan (2012a) "Nineteenth Century Race, Body Mass, and Industrialization: Evidence from American Prisons," *Journal of Interdisciplinary History* 42, pp. 371-391.

Carson, Scott Alan. (2012b). "A Quantile Approach to the Demographic, Residential, and Socioeconomic Effects on 19th Century African-American Body Mass Index Values" *Cliometrica.* 6(2), pp. 193-209.

Carson, Scott Alan. (2013). "Body Mass, Wealth, and Inequality in 19th century U.S. Joining the Debate Surrounding Equality and Health." *Economics and Human Biology* 11(1). pp. 90-94.

Carson, Scott Alan. (2015a). "Biological Conditions and Economic Conditions: Nineteenth-Century Stature on the U. S. Great Plains." *Human Nature* 26, pp. 123-142.

Carson, Scott Alan. (2015b). "A Weighty Issue: Diminished 19th Century Net Nutrition among the US Working Class." *Demography,* 52. pp. 945-966.

Carson, Scott Alan. (2015c). "Biology, Complexion, and Socioeconomic Status: Accounting for 19th Century US BMIs by Race." *Australian Economic History Review*. Forthcoming.

Carson, Scott Alan. (2015d). "The Mexican Calorie Allocation among the Working Class in the 19th Century American West." *Essays in Economic and Business History.* 26, pp. 33-50.

Case, A. and Paxson, C. (2008). Height, health, and cognitive function at older ages. *American Economic Review,* 98, 463-467.

Comer, James (2000) "North America from 1492 to the Present." In Kenneth Kiple and Kriemheld Ornelas (Eds.). *The Cambridge Word History of Food.* Cambridge: Cambridge University Press. pp. 1304-1323.

Cummings, Richard O. 1940. *The American and his Food.* Chicago: University of Chicago Press.

Dawes, Laura. (2014). *Childhood Obesity in America*. (Cambridge: Harvard University Press).

Deaton, A. (2008). Height, health, and inequality: The distribution of adult heights in India. *American Economic Review,* 98, pp. 468-474.

Deaton, Angus. (2013). *The Great Escape: Health, Wealth, and the Origins of Inequality."* Princeton: Princeton University Press.

Edwards, L. and Grossman, M. (1978). Children's Health and the Family. *National Bureau of Economic Research.*

Floud, Roderick, Kenneth Wachter, and Annabel Gregory. (1990). *Height, Health, and History: Nutritional Status in the United Kingdom, 17850-1980.* Cambridge: Cambridge University Press.

Fogel, Robert W. and Stanley Engerman, *Time on the Cross.* New York: W. W. Norton, 1974.

Fogel, R. (1994). "Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy." *American Economic Review* 84(3): 369-395.

Herbert, P., Richards-Edwards, J., Manson, J.A., Ridker, P., Cook, N., O'Conner, G., Buring, J., and Hennekens, C. (1993) "Height and Incidence of Cardiovascular Disease in Male Physicians." *Circulation* 88, pp.1437-1443.

Hilliard, Samuel B. *Hog, Meat and Hoecake: Food Supply in the Old South, 1840-1860.* Carbondale, IL: Southern Illinois University Press. 1972.

Hirschi, Travis and Michael Gottfredson. (1983) "Age and Explanation of Crime." *American Journal of Sociology*, 89(3), pp. 552-584.

Komlos, J., (1987). The Height and Weight of West Point Cadets: Dietary Change in Antebellum America. *Journal of Economic History* 47, 897-927.

Komlos, J., Coclanis, P., 1997. On the Puzzling Cycle in the Biological Standard of Living: The Case of Antebellum Georgia. *Explorations in Economic History* 34, pp. 433-59.

Leamer, E. 2010. "Tantalus on the road to asymptopia." *Journal of Economic Perspectives* 24, pp. 31-46.

Leamer, E. 1983. Let's take the con out of econometrics. *American Economic Review* 73, pp. 31-43.

Margo, R., and Steckel, R. (1982). Heights of American Slaves: New Evidence on Nutrition and Health. *Social Science History,* 6(4), pp. 516-538.

Margo, R., and Steckel, R. (1992). The Nutrition and Health of Slaves and antebellum Southern whites." In R. W. Fogel & S. L. Engerman, (Eds.), *Without Consent or Contract: Conditions of Slave Life and the Transition to Freedom,* (pp. 508-521). New York: Norton.

Mifflin, M.D., St Jeor, ST, Hill, LA, Scott, BJ, Daugherty, SA and YO Koh (1990). "A new

predictive equation for resting energy expenditure in healthy individuals." *American Journal of Clinical Nutrition*, Vol 51, pp. 241-247.

Miller, Jane E. (2005). *The Chicago Guide to Writing about Multivariate Analysis.* Chicago: University of Chicago Press.

Ransom, Roger and Richard Sutch. (1977). *One Kind of Freedom: The Economic Consequences of Emancipation.* Cambridge: Cambridge University Press.

Shergold, Peter R. 1982. *Working Class Life: The American Standard in Comparative Perspective, 1899-1913.* Pittsburgh: University of Pittsburgh Press.

Sokoloff, K., and Villaflor, G. (1982). Early Achievement of Modern Stature in America. *Social Science History,* 6, 453-481.

Sorkin, John, Denis Muller, and Reubin Andres. 1999. "Longitudinal Change in the Heights of Men and Women: Consequential Effects on Body Mass Index." *Epidemiologic Reviews.* 21, 2, pp. 247-260.

Sorkin, John, Denis Muller, and Reubin Andres. 1999. "Longitudinal Change in Height of Men and Women: Implicaitons for Interpretation of the Body Mass Index, The Baltimore Longitudinal Study of Aging." *American Journal of Epidemiology* 150, 9, pp. 969-977.

Steckel, R. H. (1979). Slave Height Profiles from Coastwise Manifests. *Explorations in Economic History,* 16, 363-380.

Steckel, Richard (1983) "Height and Per Capita Income," Historical Methods*,* 16: 1-7.

Steckel, R. H. (1995). Stature and the Standard of Living. *Journal of Economic Literature* 33, 1903-1940.

Stigler, George (1958). "Price and non-Price Competition, *Journal of Political Economy* 76, 1, pp. 149-154.

Subranica, S. V. and Kawachi, I. (2004). "What Have We Learned So Far? *Epidemiological Reviews* 26, pp. 78-91.

Wagner, D. R. and V. H.Heyward, 2000. Measures of composition in blacks and whites: a comparative review. *American Journal of Clinical Nutrition* 71: 1392-1402.

Wahl, Jenny Bourne, 1996, "The Jurisprudence of American Slave Sales," *The Journal of Economic History,* 56(1), pp. 143-169.

Wahl, Jenny Bourne, 1997, "Legal Constraints on Slave Masters: the Problem of Social Cost," *The American Journal of Legal History,* 1997, pp. 1-24.

Wilkinson, R. G. and K. E. Pichett (2006). "Income Inequality and Population Health: A Review and Explanation of the Evidence. *Social Science and Medicine*, 62, pp. 1768-1784.

Zimran, Ariell (2015). "Does Sample-Selection Bias Explain the Industrialization Puzzle? Evidence from Military Enlistment in the Nineteenth-Century United States." http://aez.econ.northwestern.edu/zimran_height_selection.pdf.