

NET NUTRITION AND THE TRANSITION FROM 19TH CENTURY BOUND TO FREE-LABOR: ASSESSING DIETARY CHANGE WITH DIFFERENCES-IN-DECOMPOSITIONS

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Abstract: Average stature reflects cumulative net nutrition and health during economic development. This study introduces a difference-in-decompositions approach to show that although 19th century African-American cumulative net nutrition was comparable to working class whites, it was made worse-off with the transition to free-labor. Average stature reflects net nutrition over the life-course, and adult blacks born under bound-labor had greater age related statures loss than blacks under free-labor. Agricultural worker's net nutrition was better than workers in other occupations and was better-off under free-labor and industrialization. Within-group stature variation was greater than across-group variation, and white within-group stature variation associated with socioeconomic status was greater than African-Americans.

Keywords: Stature variation, cumulative net nutrition, Oaxaca decomposition

JEL Codes: C1, C4, D1, I1, N3

1. INTRODUCTION

The late 19th and early 20th century U.S. political transition from bound to free-labor changed the economic, legal, and social institutions related to health and net nutrition for both African and European Americans. Arnold Plant (1947, pp. 3–16), Woodward (1951, p. 134), and Tribe (2009, pp. 80 and 92) propose that lower socioeconomic status whites under free-labor were unable to compete with recently freed slaves and were made worse-off with the transition to free-labor [Donald (1995, p. 24 and 417)]. On the other hand, if whites with the transition

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illustrated discrimination, blacks would not have made as much economic, legal, and social progress because whites erected barriers to black material progress [Becker (1957, pp. 75–80), Becker (1993, pp. 188–190), Higgs (1977, pp. 133–134)]. Moreover, free-whites had an institutionalized advantage in their access to legal institutions, property rights, and human capital [Butler et al. (1989)]. An extensive research shows how African-American statures compared to European-Americans who were allocated adequate nutrition under bound-labor, which provided them with sufficient nutrition to perform work [Fogel and Engermann (1974, pp. 109–117), Fogel (1989, pp. 132–142), David et al. (1976, pp. 178–184), Kahn (1992, pp. 525–528), Margo and Steckel (1992, pp. 517–519)]. Under free-labor, conditions were altered, changing the economic opportunities facing both blacks and whites, yet it is unclear how white and black net nutrition varied with the transition to free-labor.¹ Subsequently, if white discrimination against African-Americans increased with the transition to free-labor, lower socioeconomic white statures would have increased relative to blacks, and black statures would have been worse-off with the transition to free-labor.

A population's average stature reflects the cumulative net difference between calories consumed and calories required for work and to withstand the physical environment, and the use of height data to measure net nutrition is now a well-accepted measure in economic development studies. Stature is related to health and labor market success, and taller individuals have greater access to opportunity and wages [Fogel (1994, p. 375), Case and Paxson (2008a), Case and Paxson (2008b), Hammermesh and Biddle (1994), Persico et al. (2004), Gao and Smyth (2010), Xiang and An (2015)]. Throughout life, shorter individuals with low body mass have greater mortality risk, and shorter individuals are more likely to die from cardiovascular disease, various cancers, and stroke [Davey-Smith et al. (2000), Paajanen et al. (2010)]. On the other hand, taller stature is associated with aortic and pulmonary aneurisms [Brakken et al. (2010), Miedema et al. (2014), Emerging Risk Factors Collaboration (2012)]. Height is also related to cognition. With the transition to a free-labor force, black and white height differences varied and reflects how economic well-being changed by race, which reflects access to available resources, mortality risk, and labor market productivity [Persico et al. (2004), Perkins et al. (2016, pp. 152–157)].

It is against this backdrop that this study uses stature as a measure for cumulative net nutrition to assess how late 19th and early 20th century black and white statures varied with the transition to free-labor. Three questions are considered when evaluating the white and black stature transition to free-labor, and a difference-in-decompositions technique is introduced to isolate sources of stature variation between bound and free-labor. First, how did white and black statures vary with the transition to free-labor? White relative to black statures increased with the transition, and white within-group stature returns associated with socioeconomic status increased the most. Second, much has been written regarding black youth stature variation compared to whites under bound-labor. How did white and black youth and adult statures vary by age with the transition to free-labor? Adult

age-related black stature loss was less than under free-labor, indicating that although slaves were allocated sufficient calories to perform work under slavery, the transition to free-labor improved the age-related cumulative net nutrition for African-Americans. Third, what were the greatest sources of white and black stature variation with the transition to free-labor, and did white and black statures vary more across or within race categories? On its surface, statures should have varied more across white and black statures; nonetheless, statures varied the most within racial categories, and socioeconomic status and nativity were the greatest source of the white within-group stature increase.

2. DATA

Data for this project is the result of an extensive effort to collect and collate a broad set of physical characteristics from late 19th and early 20th century U.S. prison records. All prisons were contacted on multiple occasions, and available and affordable records were entered into a master data set. These records include Arizona, Colorado, California, Idaho, Illinois, Kentucky, Maryland, Mississippi, Montana, Nebraska, New Mexico, Ohio, Oregon, Pennsylvania, Philadelphia, Tennessee, Texas, Utah, and Washington. Reception dates began as early as 1803 and lasted through 1943. Birth dates begin in the 1730s and reach the 1920s. At the time of incarceration, enumerators recorded a broad set of characteristics, including age, occupations, race, birth period, nativity, and height.

Military and prison records are two sources used to evaluate late 19th and early 20th century stature variation. While plentiful, military statures represent conditions among higher socioeconomic groups and may suffer from an arbitrary truncation point imposed by minimum stature requirements for service [Fogel et al. (1978); Sokoloff and Villaflor (1982, pp. 456–458)]. Prison records are an alternative to military data and may have the advantage of being drawn from individuals with lower socioeconomic status, that segment of society most vulnerable to economic change. Prison records are, however, not above reproach. For example, inmates did not have sufficient income and wealth at the time of trial to afford legal counsel; therefore, poorer individuals may have been more likely to be incarcerated. On the other hand, prison officials may have judged that taller individuals were more likely to commit crimes because they were in better physical condition, which gave them an advantage in criminal interactions. Subsequently, law enforcement may have been more likely to incarcerate taller individuals.²

There has been a recent challenge to the well-established view that statures decreased during the 19th century's second and third quarters that maintains sample selection is responsible for the decrease in statures rather than a genuine decrease in net nutrition [Bodenhorn et al. (2015)]. However, this revised view may itself be the result of sample selection, and is not settled in the literature [Zimran (2015), Komlos and A'Hearn (2016)]. For example, recent criticisms of the antebellum paradox fail to address evidence that urban statures are shorter and decreased

with the separation of food consumption from food production, which is observed across disciplinary studies [Zehetmayer (2011), Haines et al. (2003, pp. 398–407), Davidson et al. (2002, p. 268), Steckel and Rose (2002, p. 575), Carson (2008a, p. 368)]. Statures were also shorter in geographic regions with higher disease rates [Haines et al. (2003, p. 406)], which are established explanations for the antebellum paradox. The difference-in-decompositions presented here helps identify and control sample differences. In sum, it is not clear which segment of society prison records represent; however, it is generally accepted that prison records more likely represent conditions among lower socioeconomic groups.

Because racial classification was a primary means of identifying individuals within prisons, enumerators were thorough when recording inmate complexion. Complexion was also used to identify an inmate if they escaped and were recaptured. Individuals of African descent were classified as black, dark black, brown, chocolate, and various shades of “mulatto.” Individuals of European ancestry born in the United States were classified as white, fair, light, medium, and dark. The European complexion scheme is further supported because inmates claiming European nativity in U.S. prisons were also recorded as white, light, fair, medium, and dark. Until the 1930s, in both U.S. federal censuses and prisons, the term “mulatto” was used to describe persons of mixed African and European ancestry. However, persons of mixed African and European ancestry are recorded as “mixed-race” in the results that follow.³ To isolate how economic and social processes were related before and after bound-labor, only black and white males are used in this study [Carson (2009b, 2011a, 2013a)].

Occupations are an important means of classifying socioeconomic status, and seven occupation categories are used here: white-collar, skilled, farmers, ranchers, farm laborers, unskilled, and workers with no recorded occupation. Bankers, merchants, and physicians are classified as white-collar workers. Blacksmiths, butchers, and tailors are classified as skilled workers. General farmers are classified as farmers, and ranchers and stockmen are classified as ranchers. There are farm and common laborers in the sample. Because farm laborers likely came to maturity under better biological conditions, including them in a single unskilled occupation category downwardly biases farm labor and upwardly biases common unskilled workers’ cumulative net nutrition [Margo and Steckel (1992, pp. 514–517), Carson (2011b, 2013b)]. Therefore, common and farm laborers are separated in the results that follow. A seventh category is included for workers with no listed occupations.

Figure 1 plots average white and black statures for birth between 1760 and 1920. White statures were taller than black statures and conform to the antebellum paradox [Komlos (1987), Carson (2009c)]. White’s greatest cumulative net nutrition advantage was around 1810, when bound-labor was entrenched in U.S. labor markets. On the other hand, average black stature increased relative to whites in the early 19th century and continued through the 1850s, which is consistent with the late antebellum cotton boom that favored black net nutrition [Wright (1978), Rees et al. (2003), Carson (2009b, p. 824)]. Before 1920, the smallest white-black stature

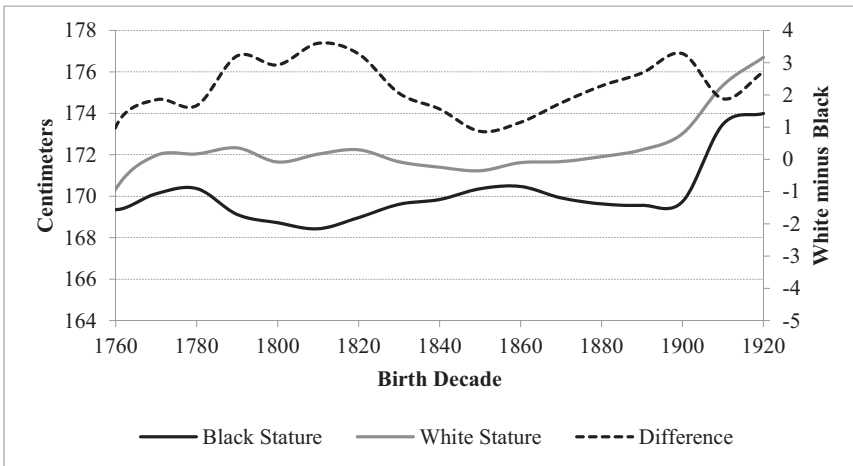


FIGURE 1. Late 19th and early 20th century stature variation by birth over time. Source: See [Table 1](#).

gap was in the 1850s and indicates that average statures were most similar just prior to the Civil War. Given the stature variation in [Figure 1](#), the most reasonable period to specify a change in white and black cumulative U.S. net nutrition is, therefore, the 1865 transition from bound to free-labor.

White and black statures are partitioned into four groups: whites and blacks born before 1866 and whites and blacks born after 1865. A principle concern in measuring the effect of the transition from bound to free-labor is isolating African-American workers born before 1865 who were born into slavery. The Maryland prison is the only institution which, for at least a time, recorded whether or not an inmate was a slave. However, this variable was only recorded for a short period. For the remaining prisons, no effort was made to record slave status, and we are unable to further distinguish between African-Americans who were born before 1865 born under slavery. However, conditions throughout the United States for lower socioeconomic status blacks before emancipation reflected the disparate slave system, and racial disparity was the norm throughout the antebellum period. Under bound-labor, slave law reflected plantation law, where plantation owners were allowed to punish their slaves on their masters' plantations to pay their social debt while not withholding slave labor from plantation owners [Komlos and Coclanis (1997, p. 436), Wahl (1996, 1997), Friedman (1993)]. Moreover, the effects of slave birth for young blacks born under slavery lingered into the decade following emancipation.

Given the primary means to identify slave birth for African-Americans is nativity, it is valuable to assess antebellum net nutrition conditions encountered by slaves. Using skeletal remains from Arkansas and Texas, two slave holding states, [Davidson et al. (2002, pp. 268–273)] demonstrates childhood was marked by

anemia, stress, accidents, high mortality, small pox, infectious diseases, cholera, and epidemic diseases were common. Adult slave skeletal remains exhibited high workloads, poor dental health, and accidents; syphilis and tuberculosis were later common. Although conditions were difficult for freed-slaves, like European-Americans, the antebellum Southwest offered free African-American limited opportunity. Alternatively, conditions facing free-blacks in the urban Northeast were better because the institution of slavery was a southern concern [Rathbun and Steckel (2002, p. 221)].

Table 1 illustrates that throughout the late 19th and early 20th centuries that whites were a larger portion of the prison population and more likely to be in white-collar, skilled workers, and agricultural occupations. Blacks were always less likely than whites to be skilled, and the proportion of blacks in skilled occupations was comparable before and after the transition to free-labor. However, with the end of slavery, blacks were more likely to own or tenant land and took up a larger proportion in agricultural occupations for birth after 1865 [Maloney (2002)]. Blacks were more likely to be unskilled and workers without occupations, and the proportion of unskilled whites increased under free-labor, which is likely related to immigration [Cohn (2009)]. Nativity from the Northeast, Middle Atlantic, and Southeast decreased over time, while nativity from the Plains, Southwest, and Far West increased. The proportion from the Great Lakes remained about the same throughout the period. While there was a considerable share of immigrants in prison records, to isolate the U.S. labor market transition from bound to free-labor, only U.S. born individuals are considered here. There was a greater share of African-Americans after 1865. Residence distributions indicate the West was the geographic region that had the highest proportion of whites compared to blacks; however, there was a higher proportion of blacks compared to whites in urban Philadelphia. Northern prisons had higher ratios of whites to African-Americans, and blacks relative to whites decreased over time. In sum, the prison composition for individuals born under both bound and free-labor was more likely young, unskilled black workers; however, black farmers became more prominent over time.

3. ECONOMETRIC MODEL

Separating results into treatment and control groups before and after an event is a practical means to isolate variation due to changes in returns to characteristics and changes due to average characteristics [Oaxaca (1973), Lee (2005)]. If there is a measureable difference between returns to characteristics before and after bound-labor with similar average characteristics, the effects of the transition to free-labor is more likely due to the transition. If, however, there is little difference between returns to characteristics before and after bound-labor and a large difference between average characteristics, the effects of the transition are associated with differences in sample compositions.

TABLE 1. Average characteristics for blacks and whites bound and free labor

	White, bound-labor		Black, bound-labor		White, free labor		Black, free labor	
	Average	S.D.	Average	S.D.	Average	S.D.	Average	S.D.
Average age	171.51	6.68	170.24	7.10	171.92	6.57	169.91	7.14
Ages	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Teens	7,830	9.51	3,928	12.07	13,320	15.11	14,282	25.12
20s	34,958	42.47	15,095	46.38	51,110	57.99	32,444	57.07
30s	20,171	24.51	6,924	21.28	18,278	20.74	8,147	14.33
40s	11,460	13.92	3,835	11.78	4,649	5.27	1,801	3.17
50s	5,895	7.16	2,029	6.23	690	0.78	161	0.28
60s	1,999	2.43	732	2.25	95	0.11	12	0.02
Occupations								
White-Collar	9,040	10.98	1,381	4.24	11,286	12.80	1,910	3.36
Skilled	21,892	26.60	3,681	11.31	21,189	24.04	5,749	10.11
Farmer	10,235	12.43	2,662	8.18	11,086	12.58	5,963	10.49
Rancher	230	0.28	10	0.03	983	1.12	29	0.05
Farm laborer	279	0.34	65	0.20	543	0.62	92	0.16
Unskilled	31,147	37.84	17,831	54.79	38,495	43.67	33,570	59.05
No occupation	9,490	11.53	6,913	21.24	4,560	5.17	9,534	16.77
Nativity								
Northeast	3,523	4.28	200	0.61	1,657	1.88	170	0.30
Middle Atlantic	28,868	35.07	4,370	13.43	13,262	15.05	2,359	4.15
Great lakes	20,797	25.27	1,606	4.94	20,925	23.74	2,836	4.99
Plains	6,485	7.88	2,252	6.93	20,664	23.44	6,680	11.75
Southeast	17,503	21.26	19,124	58.77	16,640	18.88	28,139	49.50
Southwest	2,609	3.17	4,837	14.86	8,697	9.87	16,219	28.53
Far West	2,528	3.07	154	0.47	6,297	7.14	444	0.78

TABLE 1. Continued

	White, bound-labor		Black, bound-labor		White, free labor		Black, free labor	
	Average	S.D.	Average	S.D.	Average	S.D.	Average	S.D.
Residence								
Illinois	10,915	13.26	1,335	4.10	6,281	7.13	1,782	3.13
Kentucky	4,221	5.13	2,864	8.80	2,468	2.80	3,393	5.97
Mississippi	683	0.83	1,453	4.46	667	0.76	2,732	4.81
Missouri	10,986	13.35	2,848	8.75	14,396	16.33	8,200	14.42
Nebraska	1,588	1.93	128	0.39	9,660	10.96	1,161	2.04
Ohio	15,601	18.95	2,484	7.63	9,614	10.91	2,841	5.00
PA, East	6,611	8.03	1,666	5.12	3,092	3.51	1,198	2.11
PA, West	4,424	5.37	518	1.59	2,159	2.45	596	1.05
Philadelphia	4,402	5.35	1,930	5.93	1,707	1.94	1,190	2.09
Tennessee	3,946	4.79	7,388	22.70	6,529	7.41	13,944	24.53
Texas	6,044	7.34	9,255	28.44	10,095	11.45	18,045	31.74
Western States	12,892	15.66	674	2.07	21,474	24.36	1,765	3.10
Total	82,313	100.00	32,543	100.00	88,142	100.00	56,847	100.00

Source: Arizona State Library, Archives and Public Records, 1700 W. Washington, Phoenix, AZ 85007; Colorado State Archives, 1313 Sherman Street, Room 120, Denver, CO 80203; California State Archives, 1020 O Street, Sacramento, CA 954814; Idaho State Archives, 2205 Old Penitentiary Road, Boise, Idaho 83712; Illinois State Archives, Margaret Cross Norton Building, Capital Complex, Springfield, IL 62756; Kentucky Department for Libraries and Archives, 300 Coffee Tree Road, Frankfort, KY 40602; Missouri State Archives, 600 West Main Street, Jefferson City, MO 65102; William F. Winter Archives and History Building, 200 North St., Jackson, MS 39201; Montana State Archives, 225 North Roberts, Helena, MT, 59620; Nebraska State Historical Society, 1500 R Street, Lincoln, Nebraska, 68501; New Mexico State Records and Archives, 1205 Camino Carlos Rey, Santa Fe, NM 87507; Ohio Archives Library, 800 E. 17th Avenue, Columbus, OH 43211; Oregon State Archives, 800 Summer Street, Salem, OR 97310; Pennsylvania Historical and Museum Commission, 350 North Street, Harrisburg, PA 17120; Philadelphia City Archives, 3101 Market Street, Philadelphia, PA 19104; Tennessee State Library and Archives, 403 7th Avenue North, Nashville, TN 37243 and Texas State Library and Archives Commission, 1201 Brazos St., Austin TX 78701; Utah State Archives, 346 South Rio Grande Street, Salt Lake City, UT 84101; Washington State Archives, 1129 Washington Street Southeast, Olympia, WA 98504.

A popular method to establish causal inference in the quasi-experiment literature is a difference-in-difference estimator, which mimics an experimental research design using observational data. The difference-in-difference estimator also isolates the treatment effect on the response variable by comparing average changes between treatment and control groups.⁴ A Blinder–Oaxaca decomposition is a statistical procedure used to partition the difference between response variables into differences due to characteristic returns and average characteristics [Oaxaca (1973)].

Let Y_c and Y_t be control and treatment response models.

$$Y_c = \alpha_c + \beta_c \bar{X}_c \tag{1}$$

and

$$Y_t = \alpha_t + \beta_t \bar{X}_t \tag{2}$$

where α_c and α_t are the control and treatment group autonomous components. β_c and β_t are control and treatment stature partial derivatives with respect to characteristics. \bar{X}_c and \bar{X}_t are control and treatment average characteristic matrices. A decomposition separates the difference between response variables.

$$\Delta Y = Y_t - Y_c = \alpha_t + \beta_t \bar{X}_t - \alpha_c - \beta_c \bar{X}_c \tag{3}$$

Adding and subtracting $\beta_t \bar{X}_c$ to the right-hand side, and collecting like terms is the decomposition

$$\Delta Y = Y_t - Y_c = (\alpha_t - \alpha_c) + (\beta_t - \beta_c) \bar{X}_c + (\bar{X}_t - \bar{X}_c) \beta_t \tag{4}$$

The objective of a difference-in-decompositions is to partition the difference in response variables into percent differences due to returns to characteristics and average characteristics between bound and free-labor. These percent differences-in-decompositions are the differences between how the response variable changes with the transformation to free-labor.⁵

Let white and black bound and free-labor statures be expressed in vectors.

$$S_w^{\text{bound}} = \alpha_w^{\text{bound}} + \beta_w^{\text{bound}} \bar{X}_w^{\text{bound}} \tag{5}$$

$$S_b^{\text{bound}} = \alpha_b^{\text{bound}} + \beta_b^{\text{bound}} \bar{X}_b^{\text{bound}} \tag{6}$$

$$S_w^{\text{free}} = \alpha_w^{\text{free}} + \beta_w^{\text{free}} \bar{X}_w^{\text{free}} \tag{7}$$

$$S_b^{\text{free}} = \alpha_b^{\text{free}} + \beta_b^{\text{free}} \bar{X}_b^{\text{free}} \tag{8}$$

where S_w^{bound} are white statures born before 1866 and S_w^{free} are whites born after 1865. S_b^{bound} and S_b^{free} are defined similarly for African-Americans.⁶

There are two ways to compare the effects of an event between groups: across and within-groups. The across-group decomposition isolates the white-black stature difference between bound and free-labor. The within-group decomposition isolates the difference in response variables within groups between bound and free-labor. It is also noteworthy that, unlike a difference-in-difference estimator, the

difference-in-decompositions estimator order varies between across and within estimators. Difference-in-decompositions are first decomposed, and the decompositions are differenced, resulting in differences between across and within group decompositions. The white and black across-group difference-in-decompositions is considered first, followed by a within-group decomposition.

3.1. Across-Groups Decomposition

The across-group decomposition identifies white and black stature differences with the transition to free-labor attributable to returns to characteristics versus average characteristics. To start, the across-group difference-in-decompositions is calculated by taking the white and black stature decompositions under free and bound-labor. For both the free and bound-labor decompositions, white stature is the base stature because whites were, on average, taller than blacks [Carson (2009c)].

$$\Delta S^{\text{free}} = (\alpha_w^{\text{free}} - \alpha_b^{\text{free}}) + ((\beta_w^{\text{free}} - \beta_b^{\text{free}}) \bar{X}_b^{\text{free}}) + ((\bar{X}_w^{\text{free}} - \bar{X}_b^{\text{free}}) \beta_w^{\text{free}}) \tag{9}$$

$$\begin{aligned} \Delta S^{\text{bound}} = & (\alpha_w^{\text{bound}} - \alpha_b^{\text{bound}}) + ((\beta_w^{\text{bound}} - \beta_b^{\text{bound}}) \bar{X}_b^{\text{bound}}) \\ & + ((\bar{X}_w^{\text{bound}} - \bar{X}_b^{\text{bound}}) \beta_w^{\text{bound}}) \end{aligned} \tag{10}$$

The difference-in-decompositions is the difference in the free and bound-labor across group decompositions.

$$\begin{aligned} \Delta S_{\Delta} = \Delta S^{\text{free}} - \Delta S^{\text{bound}} = & (\alpha_w^{\text{free}} - \alpha_b^{\text{free}}) + ((\beta_w^{\text{free}} - \beta_b^{\text{free}}) \bar{X}_b^{\text{free}}) \\ & + ((\bar{X}_w^{\text{free}} - \bar{X}_b^{\text{free}}) \beta_w^{\text{free}}) - (\alpha_w^{\text{bound}} - \alpha_b^{\text{bound}}) \\ & - ((\beta_w^{\text{bound}} - \beta_b^{\text{bound}}) \bar{X}_b^{\text{bound}}) - ((\bar{X}_w^{\text{bound}} - \bar{X}_b^{\text{bound}}) \beta_w^{\text{bound}}) \end{aligned} \tag{11}$$

which is rewritten as

$$\begin{aligned} \Delta S_{\Delta} = \Delta S^{\text{free}} - \Delta S^{\text{bound}} = & (\alpha_w^{\text{free}} - \alpha_b^{\text{free}}) - (\alpha_w^{\text{bound}} - \alpha_b^{\text{bound}}) \\ & + ((\beta_w^{\text{free}} - \beta_b^{\text{free}}) \bar{X}_b^{\text{free}}) - ((\beta_w^{\text{bound}} - \beta_b^{\text{bound}}) \bar{X}_b^{\text{bound}}) \\ & + ((\bar{X}_w^{\text{free}} - \bar{X}_b^{\text{free}}) \beta_w^{\text{free}}) - ((\bar{X}_w^{\text{bound}} - \bar{X}_b^{\text{bound}}) \beta_w^{\text{bound}}) \end{aligned} \tag{12}$$

Equation (12) is the white–black across-group stature decomposition.

3.2. Within-Group Decomposition

There was also a stature difference within white and black groups with the transition to free-labor, which illustrates how stature returns within racial groups varied with the transition to free-labor. The within-group decomposition is calculated by taking the stature difference within groups before and after bound-labor and illustrates the sources of the within-group changes associated with the transition to free-labor. Free-labor statures are the base structure.

$$\begin{aligned} \Delta S_{\text{White}} = & (\alpha_w^{\text{free}} - \alpha_w^{\text{bound}}) + ((\beta_w^{\text{free}} - \beta_w^{\text{bound}}) \bar{X}_w^{\text{bound}}) \\ & + ((\bar{X}_w^{\text{free}} - \bar{X}_w^{\text{bound}}) \beta_w^{\text{post}}) \end{aligned} \tag{13}$$

$$\begin{aligned} \Delta S_{\text{Black}} = & (\alpha_b^{\text{free}} - \alpha_b^{\text{bound}}) + ((\beta_b^{\text{free}} - \beta_b^{\text{bound}}) \bar{X}_b^{\text{bound}}) \\ & + ((\bar{X}_b^{\text{free}} - \bar{X}_b^{\text{bound}}) \beta_b^{\text{free}}) \end{aligned} \tag{14}$$

The within-group difference-in-decompositions is then derived by taking the difference between after and bound-labor.

$$\begin{aligned} \Delta S_{\Delta} = \Delta S_{\text{white}} - \Delta S_{\text{black}} = & (\alpha_w^{\text{free}} - \alpha_w^{\text{bound}}) + ((\beta_w^{\text{free}} - \beta_w^{\text{bound}}) \bar{X}_w^{\text{bound}}) \\ & + ((\bar{X}_w^{\text{free}} - \bar{X}_w^{\text{bound}}) \beta_w^{\text{free}}) - (\alpha_b^{\text{free}} - \alpha_b^{\text{bound}}) \\ & - ((\beta_b^{\text{free}} - \beta_b^{\text{bound}}) \bar{X}_b^{\text{bound}}) - ((\bar{X}_b^{\text{free}} - \bar{X}_b^{\text{bound}}) \beta_b^{\text{free}}) \end{aligned} \tag{15}$$

which is written as

$$\begin{aligned} \Delta S_{\Delta} = \Delta S_{\text{white}} - \Delta S_{\text{black}} = & (\alpha_w^{\text{free}} - \alpha_w^{\text{bound}}) - (\alpha_b^{\text{free}} - \alpha_b^{\text{bound}}) \\ & + (\beta_w^{\text{free}} - \beta_w^{\text{bound}}) \bar{X}_w^{\text{bound}} - (\beta_b^{\text{free}} - \beta_b^{\text{bound}}) \bar{X}_b^{\text{bound}} \\ & + (\bar{X}_w^{\text{free}} - \bar{X}_w^{\text{bound}}) \beta_w^{\text{free}} - (\bar{X}_b^{\text{free}} - \bar{X}_b^{\text{bound}}) \beta_b^{\text{free}} \end{aligned} \tag{16}$$

Equation (16) is the white-black within-group stature decomposition.

4. BLACK AND WHITE STATURES DURING BOUND AND FREE-LABOR

Nineteenth century black and white statures were related to age, occupations, nativity, and residence. To determine how statures and net nutrition were related by race with the transition to free labor, statures are regressed on demographics, socioeconomic status, nativity at birth, and residence. Four models are presented: whites and blacks born before 1866, and whites and blacks born after 1865.

$$\begin{aligned} \text{Cent}_i^j = & \alpha_i^j + \sum_{a=1}^{15} \beta_a \text{Age}_i^j + \sum_{l=1}^6 \beta_l \text{Occupation}_i^j + \sum_{n=1}^6 \beta_n \text{Nativity}_i^j \\ & + \sum_{r=1}^6 \beta_r \text{Residence}_i^j + \varepsilon_i^j \end{aligned} \tag{17}$$

where *i* is race and *j* is pre and post 1865 birth. Youth annual age dummy variables are included to account for how statures varied between 12 and 22. Adult age decade dummy variables are included for ages 30 through 60. Occupation dummy variables are included for white-collar, skilled, farmers, ranchers, farm-laborers, and unskilled occupations. To account for net nutrition by nativity, dummy variables are included for birth in Middle Atlantic, Great Lakes, Plains, Southeast, Southwest, and Far West regions. Residence at time of observation accounts for conditions around the time of measurement, such as local conditions that an individual reached adulthood, and in the case slaves, accounts for state-level treatment under bound-labor.

Table 2's Model 1 is white statures in centimeters as a function of age, occupations, nativity, and residence for birth before 1865. Model 2 does the same for

TABLE 2. Black and white, before and after regression models by demographics and socioeconomic status

	Model 1 White, bound-labor	Model 2 Black, bound-labor	Model 3 White, free labor	Model 4 Black, free labor
Intercept	171.65*** (0.197)	169.92*** (0.415)	170.81*** (0.231)	169.61*** (0.394)
Ages				
12	-20.46*** (0.049)	-18.81*** (0.037)	-17.40*** (0.065)	-21.93*** (0.039)
13	-14.65*** (0.048)	-16.34*** (0.031)	-13.68*** (0.038)	-15.84*** (0.033)
14	-15.05*** (0.028)	-11.31*** (0.037)	-12.87*** (0.055)	-11.37*** (0.037)
15	-9.54*** (0.022)	-8.91*** (0.035)	-8.14*** (0.032)	-7.93*** (0.028)
16	-5.95*** (0.024)	-5.66*** (0.053)	-5.00*** (0.039)	-4.94*** (0.032)
17	-3.86*** (0.019)	-3.80*** (0.044)	-2.86*** (0.029)	-3.13*** (0.023)
18	-2.71*** (0.020)	-2.61*** (0.037)	-1.54*** (0.026)	-2.09*** (0.021)
19	-1.26*** (0.014)	-1.27*** (0.036)	-1.00*** (0.020)	-1.25*** (0.014)
20	-0.972*** (0.012)	-0.940*** (0.016)	-0.432*** (0.021)	-0.386*** (0.018)
21	-0.287*** (0.013)	-0.197*** (0.018)	-0.173*** (0.012)	-0.328*** (0.011)
22	0.065*** (0.008)	0.145*** (0.018)	-0.191*** (0.006)	-0.333*** (0.008)
23-29	Reference	Reference	Reference	Reference
30s	0.066*** (0.011)	0.001 (0.015)	0.055*** (0.009)	0.202*** (0.008)
40s	-0.037** (0.014)	-0.607*** (0.013)	-0.303*** (0.018)	-0.423*** (0.014)
50s	-0.567*** (0.022)	-1.34*** (0.021)	-0.887*** (0.044)	-0.812*** (0.034)
60s	-1.05*** (0.029)	-2.00*** (0.036)	-1.48*** (0.078)	-1.25*** (0.188)
Occupations				
White-Collar	-0.716*** (0.124)	-0.638*** (0.147)	0.596*** (0.137)	0.337** (0.119)
Skilled	-0.553*** (0.128)	0.311 (0.229)	0.496*** (0.138)	0.223 (0.132)
Farmer	0.869*** (0.144)	1.28*** (0.207)	1.69*** (0.169)	1.54*** (0.118)

TABLE 2. Continued

	Model 1 White, bound-labor	Model 2 Black, bound-labor	Model 3 White, free labor	Model 4 Black, free labor
Rancher	0.572 (0.397)	1.67* (0.950)	2.19*** (0.140)	1.76*** (0.490)
Farm laborer	0.938 (0.874)	0.102 (1.02)	2.39*** (0.390)	2.31 (2.24)
Unskilled	-0.434** (0.177)	0.239 (0.174)	0.766*** (0.127)	0.750*** (0.116)
No occupation	Reference	Reference	Reference	Reference
Nativity				
Northeast	Reference	Reference	Reference	Reference
Middle Atlantic	-0.199*** (0.059)	-0.299 (0.198)	-0.074 (0.292)	0.068 (0.277)
Great lakes	0.891*** (0.100)	1.15*** (0.166)	1.03*** (0.183)	0.741 (0.427)
Plains	1.23*** (0.113)	0.624* (0.336)	1.70*** (0.170)	0.666 (0.373*)
Southeast	1.70*** (0.074)	0.630** (0.279)	1.92*** (0.213)	1.56*** (0.310)
Southwest	1.82*** (0.287)	1.46*** (0.410)	1.56*** (0.144)	2.15*** (0.399)
Far West	-0.484*** (0.049)	-0.009 (0.569)	0.949*** (0.101)	0.666 (0.557)
Residence				
Illinois	0.085 (0.076)	-0.243 (0.339)	-1.19*** (0.094)	-1.16*** (0.132)
Kentucky	2.01 ⁻⁴ (0.132)	-1.24*** (0.277)	-0.736*** (0.164)	-1.22*** (0.222)
Mississippi	-0.035 (0.289)	-0.505 (0.384)	0.753*** (0.206)	0.041 (0.172)
Missouri	-0.600*** (0.147)	-0.953*** (0.314)	-1.17*** (0.059)	-1.37*** (0.147)
Nebraska	-0.727*** (0.123)	-1.07* (0.600)	0.239*** (0.071)	0.012 (272)
Ohio	0.530*** (0.097)	0.356 (0.296)	-0.789*** (0.112)	-0.853*** (0.200)
PA, East	-1.89*** (0.096)	-1.51*** (0.268)	-2.23*** (0.099)	-2.51*** (0.360)
PA, West	-1.21*** (0.180)	-1.18*** (0.364)	-0.857*** (0.098)	-0.686*** (0.221)
Philadelphia	-1.12*** (0.200)	-0.524* (0.261)	-2.23*** (0.194)	-2.48*** (0.225)

TABLE 2. Continued

	Model 1 White, bound-labor	Model 2 Black, bound-labor	Model 3 White, free labor	Model 4 Black, free labor
Tennessee	− 0.037 (0.434)	0.350 (0.434)	− 1.38*** (0.255)	− 1.78*** (0.160)
Texas	1.79*** (0.131)	1.29*** (0.421)	0.821*** (0.145)	− 0.131 (0.117)
Western State	Reference	Reference	Reference	Reference
<i>N</i>	82,313	32,543	88,142	56,847
<i>R</i> ²	0.0819	0.0975	0.0649	0.1248

Source: See Table 1.

Notes: Robust clustered standard errors on age. *** significant at 0.01; ** significant at 0.05; * significant at 0.10.

blacks. Model 3 is the white stature model for birth after 1865, and Model 4 does the same for blacks.

4.1. Antebellum Period and Bound-Labor

Among the most telling biological relationships that illustrate the effects of the transition from bound to free-labor is the association between stature and age. Catch-up growth is the biological phenomenon where an individual who is deprived of net nutrition during early growth years experiences accelerated stature growth if sufficient net nutrition is restored before stature growth ceases, which allows them to return to their genetically predetermined growth profile [Behrman (2016)].⁷ An established pattern in ante-bellum stature studies is that for each age group, young slaves were shorter than whites but experienced greater catch-up growth as they approached adult ages and entered the adult labor force [Steckel (1986a, p. 724, 1986b), Schneider (2017)]. For the most part, a significant difference between white and black antebellum youth stature was not present. Komlos (1992, p. 300) indicates slave youth stature recovery among children was weak, and the acceleration in the rate of growth may have been confined to their late teens [Komlos (1992, p. 301, Table 10.2)].

On the other hand, older black stature loss under bound-labor was greater than whites due to years of arduous physical labor associated with age-related degenerative joint disease [Kelly and Angel (1987), Rathbun (1987, p. 244), Haboubi et al. (1990), Huang et al. (2013)]. From skeletal remains, blacks under bound-labor exhibited stature loss consistent with high workloads and physical accidents that may not have occurred had older African-Americans been free to choose their occupations and work effort devoted to physical activity throughout life [Davidson et al. (2002, pp. 267–268), Rathbun (1987, pp. 248 and 251), Rathbun and Steckel (2002, pp. 215–221)]. Moreover, the early onset of degenerative diseases at older

ages may be linked to inadequate cellular development in early life [Fogel (1994, p. 381), Schneider (2017)]. Subsequently, while black youth stature growth prior to their entry into the adult labor force has been postulated for some time, it is not supported here, and black adult age-related stature loss was greater than whites but decreased with the transition to free-labor.

Under bound-labor, stature variations by occupation results are mixed. White-collar and skilled workers likely received poor net nutrition because of the separation of food production from food consumption [Komlos (1987), Carson (2008a, pp. 366–368), Dirks (2016, pp. 39–40 and 60–62)]. Alternatively, white and black general farmers were taller than workers in other occupations, and the occupation–stature relationship for unskilled workers under bound-labor was comparable to workers with no recorded occupation [Carson (2009c, p. 155)]. Under bound-labor, individuals from urbanizing Northeast and Middle Atlantic states were shorter than individuals from elsewhere within the United States, while workers from the Great Lakes and South were taller [Table 2, Model 2; Zehetmayer (2011)]. Under bound-labor, slave owners had different incentives to change dietary mixes in response to changes in income and the relative price of food. Southern slave statures were related to efficiency wages, where slave masters and owners had incentives to prevent deterioration in slave nutrition that eroded slave owner wealth [Komlos and Coclanis (1997, pp. 453–454), Komlos (1998, pp. 785, 787, and 794)]. Moreover, under bound-labor, the regional advantage that accrued to whites did not extend to blacks native on the Plains, and U.S. born whites in the Far West had lower net nutrition compared to other areas within the United States [Carson (2013b, 2015)].

State residence variables account for regional conditions around the time of measurement, and in the case slaves, accounts for state-level treatment. White and black residence under bound-labor on the Plains and Northeast were associated with shorter statures compared to conditions in the Far West and Southwest. Far West bound-labor nativity indicates net nutrition in the Far West was below average during early economic development; however, taller Far West resident statures indicates taller individuals migrated west during bound-labor or encountered better net nutrition after their arrival in the West [Carson (2009c, pp. 152–154)].

4.2. Post Bellum Period and Free-Labor

Black and white stature variation after emancipation is noteworthy and illustrates the cumulative net nutrition changes associated with the transition to free-labor. Under free-labor, adult black age-related stature loss was also lower relative to bound-labor (Table 2, Models 1 and 2). When adult African-Americans were no longer subject to bound-labor, their cumulative net nutrition improved, especially for black men older than 50 [Higgs (1977, pp. 62–64)].

Under free-labor, the white-black occupational stature relationship improved relative to workers with no occupations [Ransom and Sutch (1977, pp. 31–39)]. Under bound-labor, occupations were not clearly defined, and the majority of workers – whether or not they listed agriculture as their primary occupation – were,

in some way, associated with agriculture, if only for transportation and household production [Dimitri et al. (2005)]. Under free-labor and early industrialization, labor markets became more specialized, and workers were separated from more nutritious diets associated with agricultural occupations [Rosenbloom (2002, p. 88)]. Moreover, the cumulative difference in net nutrition increased for white-collar and skilled workers relative to workers under bound-labor, indicating that skilled worker cumulative net nutrition improved with the transition to free-labor [Margo and Steckel (1992, p. 518)]. Higgs (1977, pp. 33–35) indicates that access to food in urban environments improved under free-labor for poor individuals and access to urban medical care was more readily available. Nonetheless, stature associated with urban residence were more adversely affected than during bound-labor, indicating that urban white-collar and skilled workers did better relative to workers with no occupations under free labor, yet the free-labor effects of urbanization were more acute.

Across the United States, white regional stature returns mostly decreased with the transition to free-labor. After slavery, individuals from the Northeast and Middle Atlantic continued to be shorter than individuals from elsewhere within the United States; Plains workers continued to be taller. However, under free-labor, white and black net nutrition in the Far West experienced a marked improvement, and cumulative net nutrition improved with immigration and the opening of the West [Turner (1893), Carson (2010, 2017), Komlos and Carson (2017)]. After 1865, immigration increased and new arrivals moved west to take advantage of abundant farm lands in recently settled Plains and Western states [Galloway and Vedder (1971, 1980), Cohn (2009, pp. 173–186), Ferrie (1999, pp. 64–70)]. In sum, older black age-related stature loss was greater under bound-labor, and cumulative net nutrition converged to occupations in a developed labor market.

5. BLACK AND WHITE STATURE RETURNS: A DIFFERENCE IN DECOMPOSITIONS APPROACH

Isolating stature changes across and within racial groups illustrates how comparative net nutrition was related to the transition to free-labor. Table 3's Panel A is the white-black stature decomposition for individuals born under free-labor (Equation (9)). Panel B is the white-black stature decomposition for individuals born under bound-labor (Equation (10)). Panel C is the across-group difference-in-decompositions, and elements are the stature percent changes across-groups associated with the transition to free-labor (Equation (12)). For example, the intercept difference between free and bound-labor demonstrates how white and black autonomous stature's non-identifiable characteristics varied with the transition to free-labor. If the difference is positive, the white autonomous stature difference increased relative to blacks under free-labor and negative if the white-black difference was greater under bound-labor. From raw means, white statures under bound-labor were 1.43 centimeters taller than blacks. Under free-labor, this advantage increased, and average white statures were 2.01 centimeters taller than

TABLE 3. Across-group difference in decompositions

Panel A Free-labor decomposition	$(\beta_w^{\text{free}} - \beta_b^{\text{free}})X_b^{\text{free}}$ Column 1 Structure	$(X_w^{\text{free}} - X_b^{\text{free}})\beta_w^{\text{free}}$ Column 2 Composition	$(\beta_w^{\text{free}} - \beta_b^{\text{free}})X_w^{\text{free}}$ Column 3 Structure	$(X_w^{\text{free}} - X_b^{\text{free}})\beta_b^{\text{free}}$ Column 4 Composition
Levels				
Sum	1.99	0.010	1.92	0.076
Total		2.00		2.00
Proportions				
Intercept	0.601		0.601	
Ages	0.037	0.222	0.020	0.239
Occupations	0.031	0.038	0.066	0.003
Nativity	0.071	-0.218	0.160	-0.307
Residence	0.255	-0.036	0.116	0.103
Sum	0.995	0.005	0.962	0.038
Total		1		1

TABLE 3. Continued

Panel B				
Bound-labor decomposition	$(\beta_w^{\text{bound}} - \beta_b^{\text{bound}})X_b^{\text{bound}}$	$(X_w^{\text{bound}} - X_b^{\text{bound}})\beta_w^{\text{bound}}$	$(\beta_w^{\text{bound}} - \beta_b^{\text{bound}})X_w^{\text{bound}}$	$(X_w^{\text{bound}} - X_b^{\text{bound}})\beta_b^{\text{bound}}$
	Structure	Composition	Structure	Composition
Levels				
Sum	2.07	-0.520	1.66	-0.116
Total		1.55		1.55
Proportions				
Intercept	1.12		1.12	
Ages	-0.026	0.370	0.020	0.324
Occupations	-0.344	-0.033	-0.373	-0.004
Nativity	0.447	-0.389	0.194	-0.136
Residence	0.140	-0.284	0.116	-0.259
Sum	1.34	-0.336	1.08	-0.075
Total		1		1
Panel C				
Difference-in-decompositions	After minus before		After minus before	
Levels				
Sum	-0.080	0.529	0.258	0.192
Total		0.450		0.450
Proportions				
Intercept	-0.518		-0.517	
Ages	0.063	-0.149	-0.42 ⁻⁴	-0.086
Occupations	0.375	0.071	0.439	0.007
Nativity	-0.376	0.171	-0.033	-0.171
Residence	0.115	0.248	-2.1 ⁻⁴	0.363
Sum	-0.341	0.341	-0.113	0.113

Source: See Tables 1 and 2.

blacks (Table 3). The difference-in-decompositions illustrates the source of white and black stature differences associated with the transition to free-labor.

5.1. Across-Group Free-Labor Decomposition

The free-labor across-group decomposition (Table 3, Panel A) demonstrates that white stature returns were positive for unidentified sources in the intercept, age, occupations, nativity, and residence. Under free-labor, white average ages were older than blacks and were a greater source of the age-related stature difference (Table 1). Residence at time of measurement accounted for the greatest white stature advantage. There were also more blacks in the South who had taller average statures because the South was agriculturally more productive than other regions within the United States [Ransom and Sutch (1977, pp. 150–155), Carson (2008b, 2009c)]. Most of the free-labor white–black stature differential was due to differences in stature returns and not average characteristics.

5.2. Across-Group Bound-Labor Decomposition

The across-group bound-labor decomposition demonstrates that white stature returns were greater than blacks for the intercept and residence (Table 3, Panel B, columns 1 and 3). However, blacks had large stature returns by socioeconomic status, and little of the difference was associated with differences in sample compositions, indicating there were large cumulative net nutrition differences by socioeconomic status under bound-labor. The greatest share of the white bound-labor stature advantage was returns to nativity. For example, whites in the Southeast stature returns were over 100% greater than Southeastern black stature returns (Table 2, Models 1 and 2). Nevertheless, under bound-labor, blacks remained in the South, where net nutrition was high [Table 3, Panel B, Columns 1 and 3; Hilliard (1972), Carson (2008b, 2009a)]. Most of the white-black bound-labor stature differential was due to returns to characteristics rather than average characteristics.

5.3. Across-Group Difference-in-Decompositions

Table 3, Panel C, illustrates that free and bound-labor percent differences were due to both changes in returns and average characteristics. Arnold Plant (1947, pp. 3–16) and Woodward (1951, p. 134) propose that after slavery, lower socioeconomic status whites were unable to compete with recently freed slaves and created political barriers to black upward economic mobility through Jim Crow laws and disparate access to human capital [Collins and Margo (2006, Tables 1, 2, and 6), Tribe (2009, pp. 80 and 92)]. By 1896, these white economic and legal advantages were codified throughout the United States under *Plessy v. Ferguson* when the Supreme Court upheld disparate white and black access to public resources. However, if whites displayed greater discrimination with the transition, blacks would not have made as much net nutritional progress. With the transition

to free-labor, the 0.450 centimeters increase in white relative to black statures demonstrates there was an increase in white relative to black net nutrition with the transition to free-labor (Table 3, Panel C).⁸ Subsequently, rather than being worse-off with the transition to free-labor, white net nutrition was better off relative to blacks with the transition to free-labor.

The difference-in-decompositions isolates other sources of the free and bound-labor differences due to characteristics and returns to average characteristics. Whites were taller than blacks under free-labor due to greater stature returns to occupations. For the most part, cumulative net nutrition by nativity in the South before and after slavery was favorable toward blacks. Consequently, the across-group difference-in-decompositions illustrates that white statures increased relative to blacks with the transition to free-labor, and the source of the advantage was greater white stature returns to socioeconomic status under free-labor.

5.4. Within Group Free and Bound Stature Decompositions

Table 4's Panel A is the white free and bound-labor within-group stature decomposition (Equation (13)). Panel B is the black free and bound-labor within-group stature decomposition (Equation (14)). Panel C is the within-groups difference-in-decompositions between free and bound-labor, which isolates the difference between how white and black statures varied within racial groups with the transition to free-labor (Equation (16)). Panel C elements are the within-group stature percent changes associated with the transition to free-labor. For example, if within-group element differences are positive, white within-group stature differences were greater with the transition to free-labor and negative if the black within-group stature differences were greater with the transition to free-labor.

5.5. White Within-Group Decomposition

Table 4's Panel A shows that white within-group cumulative net nutrition improved with free-labor, 0.396; however, from the proportion intercept, the autonomous white cumulative net-nutrition was greater under bound-labor, -2.12 . Under bound-labor, whites had an institutionalized advantage compared to their free-labor conditions, and the removal of that advantage decreased the net nutrition of whites during free-labor compared to whites during bound-labor. White within-group age returns were greater under free-labor, yet white average age was older under bound-labor. However, with the transition to free-labor, the increase in white returns to socioeconomic status offset the white within-group change in the intercept. For example, labor market development under free-labor more clearly defined occupational categories and increased white relative net nutrition, and socioeconomic status was the primary characteristic associated with improvements in white statures; there were only minor white average occupation differences. White stature returns associated with nativity were greater under free-labor (Table 3, Panel B),

TABLE 4. Within-group difference in decompositions

Panel A White decomposition	$(\beta_w^{\text{free}} - \beta_w^{\text{bound}})X_w^{\text{bound}}$ Column 1 Structure	$(X_w^{\text{free}} - X_w^{\text{bound}})\beta_w^{\text{free}}$ Column 2 Composition	$(\beta_w^{\text{free}} - \beta_w^{\text{bound}})X_w^{\text{free}}$ Column 3 Structure	$(X_w^{\text{free}} - X_x^{\text{bound}})\beta_w^{\text{bound}}$ Column 4 Composition
Levels				
Sum	-0.348	0.744	0.157	0.240
Total		0.396		0.396
Proportions				
Intercept	-2.12		-2.12	
Ages	0.039	-0.053	0.287	-0.300
Occupations	2.50	0.173	2.71	-0.043
Nativity	0.502	0.900	0.707	0.696
Residence	-1.79	0.856	-1.19	0.253
Sum	-0.877	1.88	0.395	0.605
Total		1		1

TABLE 4. Continued

Panel B				
Black decomposition	$(\beta_b^{\text{free}} - \beta_b^{\text{bound}})X_b^{\text{bound}}$	$(X_b^{\text{free}} - X_b^{\text{bound}})\beta_b^{\text{free}}$	$(\beta_b^{\text{free}} - \beta_b^{\text{bound}})X_b^{\text{free}}$	$(X_b^{\text{free}} - X_b^{\text{bound}})\beta_b^{\text{bound}}$
	Structure	Composition	Structure	Composition
Levels				
Sum	-0.328	-3.30 ⁻⁴	-0.293	-0.035
Total		-0.328		-0.328
Proportions				
Intercept	0.946		0.946	
Ages	-0.449	1.12	-0.399	1.07
Occupations	-1.02	-0.188	-1.08	-0.127
Nativity	-2.09	-0.542	-2.02	-0.609
Residence	3.61	-0.392	3.45	-0.231
Sum	0.999	9.91 ⁻⁴	0.894	0.106
Total		1		1
Panel C				
Difference-in-decompositions	White difference minus black difference			
Levels				
Sum	-0.020	0.744	0.450	0.275
Total		0.724		0.724
Proportions				
Intercept	-3.07		-0.3.07	
Ages	0.488	-1.18	0.686	-1.37
Occupations	3.51	0.360	3.79	0.084
Nativity	2.59	1.44	2.73	1.31
Residence	-5.40	1.25	-4.64	0.484
Sum	-1.88	1.88	-0.499	0.499

Source: See Tables 1 and 2.

yet free-labor nativity also had greater average returns than whites under free-labor (Table 4, Panel A).

5.6. Black Within-Group Decomposition

Stature returns within the African-American cohort with the transition to free-labor were even more pronounced than whites. In aggregate, black statures decreased with the transition to free-labor; however, the source of the variation was important. Blacks received greater cumulative net nutrition under bound-labor due to age, occupation, and nativity (Table 4, Panel B). However, black age returns were comparatively small, and black average age was older under free-labor. The greatest source of the black within-group stature variation was residence, which was considerably higher under free-labor. The average stature difference associated with socioeconomic status, nativity, and residence were larger under bound-labor. There were more blacks in the South under bound-labor, and the South was more agriculturally productive than elsewhere within the United States [Sunstrom (2013, p. 324), Farley and Allen (1987, pp. 113 and 118), Gregory (2005)]. Most of the black within-group stature difference between free and bound-labor was due to greater black free-labor returns to characteristics.

5.7. Within-Group Difference-in-Decompositions

Decomposing white and black stature differences within-groups is insightful. Table 4's Panel C shows that the white within-group free-labor statures increased by 0.724 centimeters relative to blacks; however, the negative within-group stature intercept difference, -3.07 , indicates white autonomous stature differences relative to blacks were greater under bound-labor. By ages, white stature returns were greater with the transition to free-labor; however, blacks were older under bound-labor. By occupations, the white relative to black stature gap increased considerably with the transition to free-labor, and there was little difference in occupation compositions, indicating that much of the improvement in white net nutrition was associated with free-labor structural returns to socioeconomic characteristics. There were large net nutrition returns by nativity that favored whites with the transition to free-labor, however, large net nutrition returns to residence that favored whites under bound-labor. In sum, the white within-group stature return variation associated with occupations and socioeconomic status were the primary source of the white within-group stature advantage, followed by nativity and age.

6. CONCLUSION

Plant, Woodward, and Tribe suggest that whites with the transition to free-labor were unable to compete with recently freed blacks. Beyond the Civil War itself, the greatest race related conflagration in U.S. history was the 1863 race riots in

lower Manhattan, where lower class whites were unwilling to fight to free African-Americans, in part, because they perceived free-blacks as competing with them for low skilled occupations. However, with the transition to free labor, white cumulative net nutrition improved relative to blacks, and the source of the advantage was due to greater stature returns under free-labor. Whites under free-labor were also better-off across groups relative to blacks and relative to whites under bound-labor. This study compares changes in the cumulative net nutrition of whites and blacks born before and after slavery and finds that black adult age-related stature loss under bound-labor was greater than whites. African-American adult age-related stature loss under bound-labor was likely due to years of arduous labor associated with degenerative joint disease and environmental insults unique to enslaved blacks. By occupations, the across-group difference-in-decompositions illustrates that labor market development and the transition to free-labor benefited whites more than blacks, and Southern white cumulative net nutrition was markedly better than Southern blacks under bound-labor. A priori, disparate net cumulative nutritional conditions across race suggests there should have been greater variation across rather than within groups. However, cumulative net nutrition conditions were greater within-groups, especially by socioeconomic status. Subsequently, with the transition to free-labor, there was greater cumulative net nutrition variation within rather than across-groups and white's cumulative net nutrition improved relative to African-Americans with the transition to free-labor, yet that improvement was associated with free-labor returns to characteristics.

NOTES

1 Individual statures vary due to complex interactions between genetics and the physical environment, and 60% of height in developing economies is determined by genetic factors, while nearly 80% of height is determined by genetic factors in developed economies [Cho et al. (2009), Lai (2006), Luke et al. (2001)].

2 Floud et al. (2011, p. 331) present estimates for 19th century U.S. stature variation, and their estimates are only 0.5% greater than average statures in the prison sample. In sum, there is little evidence that prisoners were targeted because of their height, and that prison records are more problematic than other samples.

3 The Arizona and Montana prisons are the only prisons that, for at least a short period, included each individual's written descriptions and photograph.

4 β_{Δ} is a consistent and unbiased estimate of the causal effect: $\beta_{\Delta} = (\bar{Y}_{t,t+1} - \bar{Y}_{t,t}) - (\bar{Y}_{c,t+1} - \bar{Y}_{c,t}) = \Delta\bar{Y}_t - \Delta\bar{Y}_c$ where $\bar{Y}_{t,t+1}$ and $\bar{Y}_{t,t}$ are conditional response variables on the treatment group before and after an event. $\bar{Y}_{c,t+1}$ and $\bar{Y}_{c,t}$ are the conditional response variable on the control group before and after the event.

5 There is a concern regarding the value of decomposing dependent variable differences into returns to characteristics and average characteristics because estimated coefficients vary with respect to the choice of the omitted category [Oaxaca and Ransom (1999)]. There is little concern about explaining the difference in dependent variable gap due to average characteristics, $(\bar{X}_t - \bar{X}_c)\beta_t$. However, because the intercept is sensitive to the omitted category, identification of $(\alpha_t - \alpha_c) + (\beta_t - \beta_c)\bar{X}_c$ is less clear. Some degree of arbitrariness is unavoidable [Fortin et al. (2011, pp. 40 and 45), Yun (2008)]. Although there are other interpretations, this "unexplained gap" is often interpreted as the difference attributed to structure.

6 a_w^{bound} and a_w^{free} are the intercepts for white males born before and after 1865; a_b^{bound} and a_b^{free} are defined in like fashion for blacks. β_w^{bound} and β_b^{bound} are the white and black stature characteristics for the bound-labor control group. β_w^{free} and β_b^{free} are defined similarly for the post transition white and black stature returns. \bar{X}_w^{bound} and \bar{X}_w^{free} the matrix of white male characteristics before and after 1865. \bar{X}_b^{bound} and \bar{X}_b^{free} are the black average characteristics defined in the same way.

7 In modern populations, over 86% of small-for-gestational-age children experience catch-up growth during the first six to 12 months of life [Albersson-Wikland and Karlberg (1995), Behrman (2016)].

8 Biases may exist because prison selection processes changed between bound and free labor; however, the difference-in-decompositions accounts for sample differences between the two periods by accounting both returns to characteristics and average characteristics, and white statures increased relative to blacks associated with socioeconomic status.

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