GEOGRAPHY AND INSOLATION IN 19TH CENTURY US AFRICAN-AMERICAN AND WHITE STATURES

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Abstract

The use of height data to measure living standards is now a well-established method in the economic literature. Moreover, while much is known about 19th century black legal and material conditions, less is known about how 19th century institutional arrangements were related to black stature. Although modern blacks and whites reach similar terminal statures when brought to maturity under optimal biological conditions, 19th century African-American statures were consistently shorter than whites, indicating a uniquely 19th century phenomenon may have inhibited black stature growth. It is geography and insolation that present the most striking attribute for 19th century black and statures, and greater insolation is documented here to be associated with taller black and white statures.

JEL Code: J15.

Keywords: nineteenth century, African-American and white stature, insolation.

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Geography and Insolation in 19th US Century African-American and White Statures

1. Introduction

Industrialization and modernization frequently bring about rising incomes, wages and life expectancy, particularly in the long run (Komlos, 1985, 1987; Floud, Wachter and Gregory, 1990, pp. 272-273; Margo, 2000; Williamson and Lindert, 1980). However, in the short run economic change also creates social turmoil, such as increasing inequality, crime and a more virulent disease environment, which leads to deteriorating biological conditions. Hence, the overall effect of industrialization on biological conditions depends on which effect dominates. A large body of evidence from diverse sources indicates that during the earliest stages of 19th century American industrialization the net effect on free populations was negative. In the case of the US Northeast, Middle Atlantic and Great Lakes regions, economic growth was associated with greater factor mobility, and greater income accumulation, which enhanced biological conditions (Atack and Bateman, 1980, p. 125; Atack and Bateman, 1987, p. 87-92; Easterlin, 1971, p. 40-41; Soltow, 1975, p. 103; Steckel, 1983 and 1995). However, these regions also experienced rapid industrialization and population growth, increasing food prices, and more virulent disease environments, which impeded biological conditions (Atack and Bateman, 1987, p. 156; Komlos, 1987, p. 918). In the South, economic activity was primarily agricultural, and Southern communities remained largely rural, where chattel slavery and later sharecropping were primary labor market institutions. There were also two prominent racial groups within the 19th century US that faced considerably diverse

material and biological conditions: African and European Americans. As Northern states industrialized and relied on abundant immigrant labor, Southern states remained rural with segregated labor markets and racial disparity.

The use of height data to measure living standards is now a well-established method in economics (Fogel, 1994, p. 138). A populations' average stature reflects the cumulative interaction between nutrition, disease exposure, work and the physical environment (Steckel, 1979, pp. 365-367; Tanner, 1962, pp. 1-27). By considering average versus individual stature, genetic differences are mitigated, leaving only the influence of economic and physical environments on stature. When diets, health and physical environments improve, average stature increases and decreases when diets become less nutritious, disease environments deteriorate or the physical environment places more stress on the body. Therefore, stature provides considerable insights into understanding historical processes and augments other welfare measures for 19th century blacks and whites. By using a new source of 19th century American prison records, the present study contrasts male heights of comparable blacks and whites in the US throughout the 19th century.

The 'antebellum paradox,' is a frequently cited phenomenon where Northern statures declined as wages, and income increased. During the second quarter of the 19th century, Northern average white statures declined (Komlos, 1987, p. 901; Steckel, 1995, p. 1920; Haines, 1998, pp. 162 and 172) and did not recover until the fourth quarter for white and free black populations. An anomalous finding is that during the 19th century male African-American statures increased during the antebellum period (Steckel and Haurin, 1994; Komlos, 1992; Margo and Steckel, 1982 and 1992; Carson, 2008).

However, if Southern planters and overseers rationally allocated slave nutrition and medical allocations to maximize slaveowner wealth, slave heights would have increased with antebellum slave values and probably decreased with the removal of the institution (Rees, Komlos, Long, Woitek, 2003, p. 22; Steckel, 1995; Komlos and Coclanis, 1997, p. 445; Komlos, 1998; Carson, 2008). Less is known about how Southern white statures varied over the 19th century (Komlos and Coclanis, 1997, p. 439).

Alternative mechanisms have been proposed for 19th century Northern black and white stature variation and include increased inequality, changes in relative food prices, decreased self-provision, increased income variability, population growth and urbanization, agricultural commercialization, changes in work intensity, climatic variation, and changes in the disease environment (Komlos, 1998; Haines, 2004, p. 252; Steckel, 2005, pp. 237-239); stature also varied by socioeconomic status and nativity. Farmers were consistently taller than non-farmers, who benefited from their close proximity to nutritious food sources and removal from population centers, where disease was most easily spread (Costa, 1993, pp. 364-367; Komlos and Coclanis, 1997, p. 441; Steckel and Haurin, 1994, p. 123; Margo and Steckel, 1983, p. 170; Sokoloff and Vilaflour, 1983, p. 463). Northeastern and Middle-Atlantic males were shorter and Southern males were taller than other Americans (Komlos and Coclanis, 1997, p. 441; Komlos, 1987, p. 902; Steckel and Haurin, 1994, p. 170; Sokoloff and Vilaflour, 1982, p. 463; Fogel, 1986, p. 500; Margo and Steckel, 1983, pp. 171-172).[1]

[1] Modern studies from Sokoloff and Vilaflour (1982, footnote 10, pp.461 and 478) suggests modern Southerners are taller than Northerners.

Any comparison between 19th century black and white statures must also account for an ironic finding. Modern black and white statures reach comparable average levels when brought to maturity under optimal biological conditions (Eveleth and Tanner, 1966, Appendix. Tables 5, 29, and 44; Tanner, 1977, pp. 341-342; Margo and Steckel, 1982). However, black and white stature comparisons in 19th century America demonstrate that blacks were consistently shorter than whites, but we are less certain of the source for this variation (Margo and Steckel, 1982; Sünder, 2004; Carson, 2007). Moreover, any explanation must account for a robust geographical finding: Southern blacks were shorter than Southern whites, and Northern blacks were shorter than Northern whites (Margo and Steckel, 1992, p. 516). Two possible explanations for this black stature deficit are that blacks were subjugated to slavery's biological effects versus black biological interactions with the physical environment that were different from that of whites. In the case of slavery's effect on stature, slave-owner feeding practices and labor demands may have distorted black stature growth throughout life (Komlos, 1998; Rees et al., 2003; Steckel, 1979; Bodenhorn, 1999 and 2001). Slave masters also had different incentives from free individuals to change dietary mixes in response to changes in relative food prices and income. Moreover, efficiency wages were related with slave statures, and slave masters had the incentive to prevent deterioration of slaves' nutritional statuses, which would erode slave owner wealth (Komlos and Coclanis, 1997, pp. 453-454; Komlos, 1998, pp. 785, 787 and 794).

The second source for 19th century black and white stature difference may be related to biology, especially its relationship to geography. Calcium and vitamin D are two chemical elements required throughout life for healthy bone and teeth formation;

however, their abundance are most critical during younger ages (Wardlaw, Hampl, and Divilestro, 2004, p. 394-396; Tortolani et al, 2002, p. 60). Calcium generally comes from dairy products, and vitamin D is not dietary but produced by the synthesis of cholesterol and sunlight in the epidermis' stratum granulosum (Holick, 2004, pp. 363-364; Nesby-O'dell, 2002, p. 187; Loomis, 1967, p. 501; Norman, 1998, p. 1108; Hollick, 2007).[2] Greater direct sunlight (insolation) produces more vitamin D, and vitamin D is related to adult terminal stature (Xiong et al, 2005, pp. 228, 230-231; X-ZLiu et al, 2003; Ginsburg et al 1998; Uitterlinden et al, 2004). However, vitamin D production also depends on melanin in the stratum corneum (Norman, 1998, p. 1108). Greater melanin (skin pigmentation) in the stratum corneum interferes with vitamin D's synthesis in the stratum granulosum, and darker pigmentation filters between 50 to 95 percent of the sunlight that reaches the stratum granulosum (Loomis, 1967, p. 502; Weisberg et al, 2004, p. 1703S; Holick, 2007, p. 270). Therefore, darker skin is considerably less efficient than lighter skin at producing vitamin D, and darker skin is more common in Southern latitudes, where more hours of direct sunlight offsets inefficient vitamin D production (Norman, 1998, pp. 1109-1110).

Black and mulatto stature differences have also been linked to pigmentation. Lighter colored 19th century blacks were consistently taller than darker pigmented blacks (Tanner, 1962, pp. 150-151; Tanner, 1977; Steckel, 1979, pp. 374-376; Margo and Steckel, 1982, pp. 532-34, Table 6; Bodenhorn, 1999, 2002; Xiong et al, 2005, pp. 228, 231; Z Liu, 2003, p. 825). A common explanation for this pattern is that 19th century social and economic forces favored fairer complexions over lighter complexions, and lighter colored blacks benefited from these social and economic institutions (Margo and

[2] There are few dietary sources of vitamin D.

Steckel, 1982, p. 521; Bodenhorn, 1999, p. 983). Nonetheless, a more complete explanation may be rooted elsewhere in biology.

It is against this backdrop that this paper uses a new 19th century data source from several US state prisons to address three questions on 19th century African-American and white statures. First, how did male statures vary across the US by nativity and race? The 19th century United States presents a broad array of environmental conditions, economic systems and social practices that influenced black and white stature variation, and prison data allow us to assess stature variation among a similar set of 19th century socioeconomic groups. Stature differences by nativity may also reflect regional income and relative food price differences. Second, after controlling for both nativity and the physical environment, how were statures related to socioeconomic status? The source of 19th century stature differences by occupations are typically attributed to the nutritional environment in which workers came to maturity. Third, a new potential source of stature variation by occupation is considered here that goes beyond the occupation-nutrition hypothesis.

2. Nineteenth Century US Prison Data

The data used here to study black and white statures is part of a large 19th century prison sample. All state prison repositories were contacted and available records were acquired and entered into a master data set. These prison records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, New Mexico, Ohio, Oregon, Pennsylvania, Texas, and Washington (Table 1). Most blacks in the sample were imprisoned in the Deep South or Border States—Kentucky, Missouri, Georgia and Texas. Most whites in the sample were imprisoned in Missouri and Texas, but Northern

whites were also from Illinois, Ohio and Pennsylvania. The Far West is also represented in the sample.

Table 1, Nineteenth Century US State Penitentiaries

	Black Youth		*White Youth*		*Black Adult*		*White Adult*	
Prison	N	Percent	N	Percent	N	Percent	N	Percent
Arizona	21	.19	245	1.45	177	.37	1,926	1.78
California	71	.63	1,116	6.59	362	.76	7,114	6.57
Colorado	113	1.01	500	2.95	808	1.70	6,521	6.02
Georgia	317	2.83	26	.15	998	2.09	131	.12
Idaho	6	.05	232	1.37	98	.21	1,842	1.70
Illinois	250	2.23	1,646	9.73	971	2.04	8,296	7.66
Kansas	232	2.07	768	4.54	745	1.56	3,314	3.06
Kentucky	1,480	13.23	1,130	6.68	4,763	10.00	5,520	5.10
Missouri	2,003	17.91	3,412	20.16	8,476	17.79	20,375	18.82
New Mexico	27	.24	245	1.45	317	.67	1,753	1.62
Ohio	734	6.56	3,041	17.97	4,545	9.54	21,800	20.14
Oregon	11	.10	241	1.42	50	.10	1,799	1.66
Pennsylvania	521	4.66	1,772	10.47	3,378	7.09	14,254	13.17
Texas	5,400	48.27	2,550	15.07	21,956	46.08	13,621	12.58
Total	11,186	100.00	16,924	100.00	47,644	100.00	108,266	100.00

Source: Data used to study black and white 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, Texas, Utah and Washington.

Notes: Stature is in centimeters. The occupation classification scheme is consistent with Ferrie (1997).

All historical height data have various biases, and prison and military records are the most common source of historical evidence for height. One common shortfall for military samples is a truncation bias imposed by minimum stature requirements (Fogel et al, 1978, p. 85; Sokoloff and Vilaflor, 1982, p. 457, Figure 1). Fortunately, prison

records do not implicitly suffer from such a constraint and the subsequent truncation bias observed in military samples. However, prison records are not above scrutiny. The prison data may have selected many of the materially poorest individuals, although there are skilled and agricultural workers in prison samples. While prison records are not random, the selectivity they represent has its own advantages in stature studies, such as being drawn from lower socioeconomic groups, who were more vulnerable to economic change (Bogin, 1991, p. 288; Komlos and Baten, 2004, p. 199). For height as an indicator of biological variation, this kind of selection is preferable to that which marks many military records – minimum height requirements for service (Fogel, 1978, p. 85; Sokoloff and Vilaflor, 1982, p. 457, Figure 1).

There also is concern over entry requirements, and physical descriptions were recorded by prison enumerators at the time of incarceration as a means of identification, therefore, reflect pre-incarceration conditions. Between 1830 and 1920, prison officials routinely recorded the dates inmates were received, age, complexion, nativity, stature, pre-incarceration occupation and crime. All records with complete age, stature, occupations and nativity were collected. There was great care recording inmate statures because accurate measurement had legal implications for identification in the event that inmates escaped and were later recaptured. Many inmate statures were recorded at quarter, eighth, and even sixteenth increments. Arrests and prosecutions across states may have resulted in various selection biases that may affect the results of this analysis. However, black and white stature variations within US prisons are consistent with other stature studies (Steckel, 1979; Margo and Steckel, 1982; Komlos, 1992; Komlos and Coclanis, 1997; Bodenhorn, 1999; Sünder, 2004). Because the purpose of this study is

19th century male black and white statures, females and immigrants are excluded from the analysis.

Fortunately, inmate enumerators were quite thorough when recording inmate complexion and occupation. For example, enumerators recorded inmates' race in a complexion category, and African-Americans were recorded as black, light-black, dark-black and various shades of mulatto (Komlos and Coclanis, 1997). Enumerators recorded white complexions as light, medium, dark and fair. The white inmate complexion classification is further supported by European immigrant complexions, who were always of fair complexion and were also recorded as light, medium and dark.[3] While mulatto inmates possessed genetic traits from both European and African ancestry, they were treated as blacks in the 19th century US and when comparing whites to blacks, are grouped here with blacks. When only black statures are considered in the regression models that follow, mulatto inmates are separated from the black reference group.

Enumerators recorded a broad continuum of occupations and defined them narrowly, recording over 200 different occupations, which are classified here into four categories: merchants and high skilled workers are classified as white-collar workers; light manufacturing, craft workers and carpenters are classified as skilled workers; workers in the agricultural sector are classified as farmers; laborers and miners are classified as unskilled workers (Tanner, 1977, p. 346; Ladurie, 1979; Margo and Steckel, 1992; p. 520). Unfortunately, inmate enumerators did not distinguish between farm and

[3] I am currently collecting 19th century Irish prison records. Irish prison enumerators also used light, medium, dark, fresh and sallow to describe white prisoners in prisons from a traditionally white population. To date, no inmate in an Irish prison has been recorded with a complexion consistent with African heritage.

common laborers. Since common laborers probably encountered less favorable biological conditions during childhood and adolescence, this potentially overestimates the biological benefits of being a common laborer and underestimates the advantages of being a farm laborer.

Table 2, National US Census and Prison Population Race, Residence and Occupations by Decade

	1860		*1870*		*1880*		*1900*		*1910*		*1920*	
Race												
White	98.38		87.67		88.29		89.22		89.22		90.06	
Black	1.62		12.63		11.71		10.78		10.78		9.94	
Residence												
Rural	77.33		75.62		69.54		61.47		53.03		46.51	
Urban >2,500	22.67		24.38		30.46		39.53		46.97		53.49	
Occupations												
Prisons	Black	White	Black	White	Black	White	Black	White	Black	White	Black	White
White-Collar	6.39	8.05	3.61	8.06	3.98	11.02	3.86	12.79	3.43	13.90	5.52	11.70
Skilled	13.86	24.74	8.42	25.04	8.38	23.23	10.55	26.60	12.88	28.38	15.17	29.57
Farmer	8.74	17.37	4.38	12.41	9.53	12.33	9.43	11.15	14.47	15.17	11.72	23.19
Unskilled	71.00	49.84	83.6	54.49	78.11	53.11	76.16	49.47	69.11	42.55	67.59	35.53
IPUMS	Black	White	Black	White	Black	White	Black	White	Black	White	Black	White
White-Collar	1.24	7.66	.41	4.82	1.09	7.08	1.60	8.64	2.09	12.20	2.10	12.19
Skilled	5.34	15.34	1.58	8.84	2.14	11.98	2.46	14.96	3.07	19.04	4.39	22.76
Farmer	7.24	30.88	8.17	17.26	19.59	24.91	21.82	18.34	25.02	18.33	26.04	18.23
Unskilled	86.17	46.11	89.84	69.07	77.17	56.02	74.13	58.07	69.83	50.43	67.47	46.82

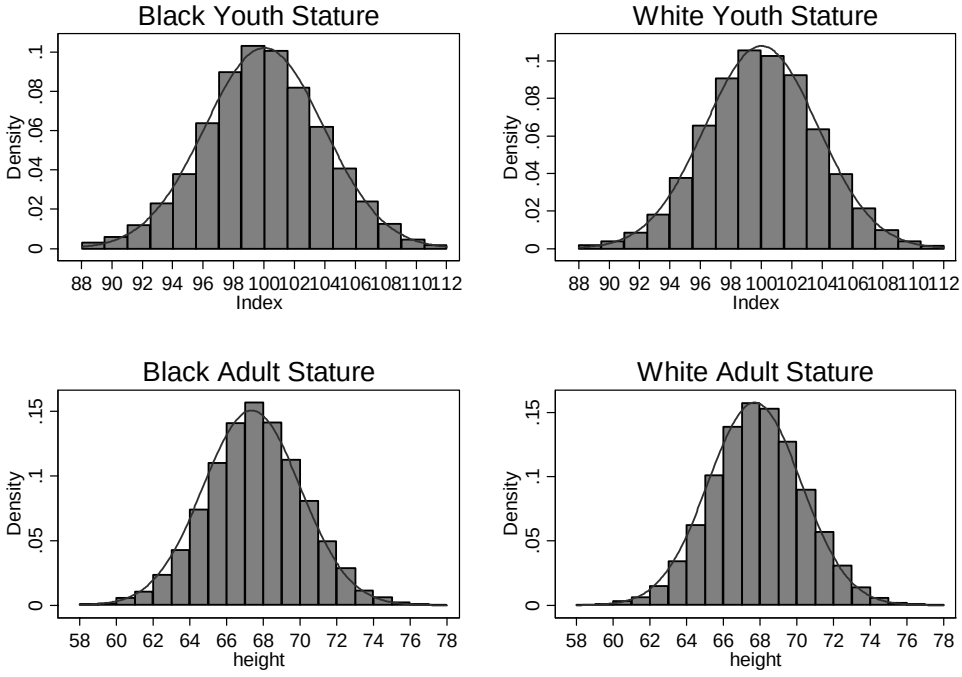
Notes: See Table 1 for prison sources. For IPUMS data, see Ruggles, Steven Matthew Sobek, Trent Alexander, Catherine A. Fitch, Ronald Goeken, Patricia Kelly Hall, Miriam King, and Chad Ronnander. *Integrated Public Use Microdata Series: Version 3.0*

[Machine-readable database]. Minneapolis, MN: Minnesota Population Center [producer and distributor], 2004.

How well US state prison populations reflect the US general population is observed by comparing prison to census population occupational and residential distributions. Table 2 illustrates that blacks in US censuses were predictably less likely than whites to be white-collar, skilled workers and farmers, and were more likely to be unskilled workers. Comparing the prison to census occupations detects the counter-intuitive result that, after controlling for race, inmates were consistently more skilled than the US population. Much of this is attributable to prisoner ages that were older than the US population, further along in the occupational life-cycle, therefore, more skilled than the US labor force. Inmates' average ages were in their mid-30s; workers in the US general population sample's average ages were in their mid-20s. However, comparing two historical data sets from different sources may be problematic because prison and census enumerators followed different recording guidelines. Given this possibility, comparing prison to census occupational distributions demonstrates that prison socioeconomic status was probably comparable with the general population's working class (Riggs, 1994, p. 64). Likewise, the US urbanized between 1860 and 1900, and urbanization occurred along racial lines. In 1860, 22.50 percent of US whites lived in urban locations; 32.92 percent of blacks lived in urban locations. By 1900, 46.11 percent of US whites lived in urban locations; 76.44 percent of blacks lived in urban locations (IPUMS, 1860, 1870, 1880 and 1900; Cuff, 2005, pp. 69-72).

Because the youth height distribution is itself a function of the age distribution, a youth height index is constructed that standardizes for age to determine youth stature normality and whether there were arbitrary truncation points imposed on inmate stature either by law enforcement or state legislation. The age adjusted youth stature index is calculated by first calculating the average stature for each age group; each observation is then divided by the average stature for the relevant age group (Komlos, 1987, p. 899). Figure 1 demonstrates that black and white statures were distributed approximately normal and there is no evidence of age heaping or arbitrary truncation points.

Figure 1, National Black and White Stature Histograms by Age Group



Source: see Table 1.

Table 3, National Prison Data White and Black Descriptive Statistics

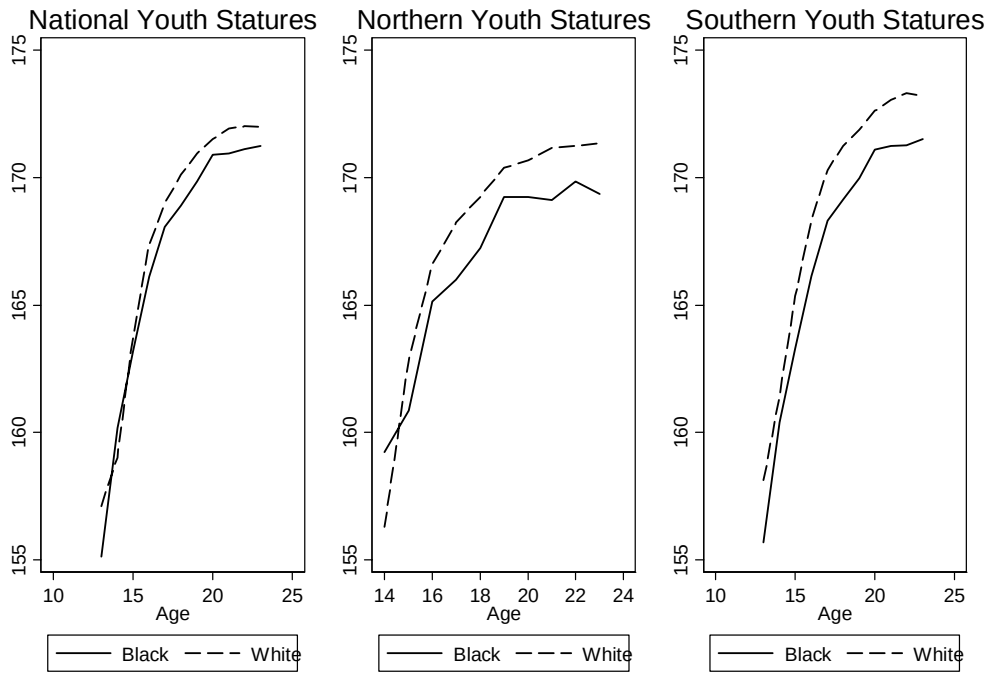
	White				*Black*				*Mean Difference*
Ages	N	Percent	Mean	S.D.	N	Percent	Mean	S.D.	
Teens	16,770	13.52	169.74	6.70	11,171	19.06	167.98	7.45	1.76
20s	63,613	51.30	171.94	6.51	31,625	53.95	171.10	6.88	.84
30s	26,886	21.68	171.98	6.48	10,196	17.39	171.29	6.72	.69
40s	10,878	8.77	171.89	6.51	3,759	6.41	170.73	6.81	1.16
50s	4,324	3.49	171.62	6.52	1,333	2.27	170.35	6.99	1.27
60s	1,298	1.05	171.26	6.71	448	.76	169.80	6.48	1.46
70s	232	.19	170.95	6.43	92	.16	169.03	5.91	1.92
Birth Decade									
1800s	906	.73	172.41	6.50	195	.33	169.42	6.27	2.99
1810s	2,467	1.99	172.52	6.56	647	1.10	169.81	6.96	2.71
1820s	4,200	3.39	172.44	6.80	848	1.45	169.29	7.02	3.15
1830s	7,988	6.45	171.79	6.66	1,514	2.58	170.19	6.86	1.60
1840s	16,506	13.32	171.46	6.52	4,516	7.70	170.22	6.88	1.24
1850s	24,982	20.15	171.30	6.69	9,853	16.81	170.71	7.13	.59
1860s	25,194	20.32	171.68	6.54	11,654	19.88	170.57	7.23	1.11
1870s	22,044	17.78	171.63	6.51	13,481	23.00	170.51	7.05	1.12
1880s	12,741	10.27	171.68	6.50	10,236	17.46	170.25	6.98	1.43
1890s	6,567	5.30	171.90	6.49	5,237	8.93	170.33	6.96	1.57
1900s	406	.33	170.67	6.30	443	.76	169.41	7.30	1.26
Occupation									
White-Collar	13,669	11.02	171.32	6.37	2,329	3.97	169.78	6.75	1.54
Skilled	31,894	25.72	171.28	6.37	6,206	10.59	170.19	6.92	1.09
Farmer	16,387	13.22	173.15	6.44	5,924	10.11	171.78	6.85	1.37
Unskilled	55,855	45.04	171.53	6.66	42,900	73.18	170.42	7.09	1.11
No Occupation	6,196	5.00	170.96	7.14	1,265	2.16	169.34	7.87	1.62
Nativity									
North East	4,004	3.23	170.70	6.31	239	.41	169.53	6.52	1.17
Middle Atlantic	32,184	25.95	170.08	6.36	4,072	6.94	168.45	6.74	1.63
Great Lakes	32,440	26.16	171.88	6.42	3,488	5.95	170.18	6.97	1.70
Plains	17,681	14.26	171.93	6.37	7,754	13.22	169.26	6.84	2.67
Southeast	21,659	17.47	172.91	6.65	21,892	37.34	170.26	7.01	2.65
Southwest	10,326	8.33	173.40	6.85	20,721	35.35	171.67	7.09	1.73
Far West	5,707	4.60	170.60	6.58	458	.78	169.24	6.77	1.36

Source: See Table 1.

Notes: Stature is in centimeters. Youth age is between ages 15 and 22. The occupation classification scheme is consistent with Ferrie (1997); The following geographic classification scheme is consistent with Carlino and Sill (2000): New England= CT, ME, MA, NH, RI and VT; Middle Atlantic= DE, DC, MD, NJ, NY, and PA; Great Lakes= IL, IN, MI, OH, and WI; Plains= IA, KS, MN, MO, NE, ND, and SD; South East= AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, and WV; South West= AZ, NM, OK, and TX; Far West= CA, CO, ID, MT, NV, OR, UT, WA, and WA. Stature difference is average white stature less average black stature.

Table 3 presents black and white inmates' age, birth decade, occupations, and nativity proportions. Although average statures are included, they are not reliable because of possible compositional effects, which are accounted for in the regression models that follow. Whites were a larger portion of the prison population than blacks; 68.03 percent of the US prison population was white. Age percentages demonstrate that black inmates were incarcerated at younger ages, while whites were incarcerated at older ages. Southern law evolved to favor plantation law, which generally allowed slave owners to recover slave labor on plantations while slaves were punished (Komlos and Coclanis, 1997, p. 436; Wahl, 1996, 1997; Friedman, 1993). Blacks were less likely to be incarcerated during the early 19th century; however, with passage of the 13th amendment, slave owners no longer had claims on black labor, and free blacks who broke the law were turned over to state penal systems to exact their social debt. Whites within 19th century US prisons were more likely than blacks to be white-collar, skilled workers, and farmers were less likely to be unskilled.

Figure 2, Regional Youth Statures by Age



Source: See Table 4.

The youth height pattern by age is itself noteworthy, and white youth were ubiquitously taller than black youth (Figure 2). Slave children's access to animal proteins—key in human growth—were restricted during childhood until their entry into the slave labor force (Steckel, 1992, pp. 500-503; Margo and Steckel, 1983; Harris, 2006, p. 100; Steckel, 1986, p. 740). Taller Southern white youth stature indicates that biological disparity started early and lasted throughout life. Moreover, that whites were also taller in the North and throughout the US indicates black-white biological disparity was the rule throughout the 19th century US.

3. The Comparative Effects of Demographics, Socioeconomic Characteristics on Black and White Stature

The timing and extent of stature variation not only reflects the cumulative relationship between diet and disease, but also socioeconomic status, birth period and nativity; insolation is added here as a possible explanation for stature variation.[4] Which of these factors dominates reveals much about 19th century conditions facing black and white Americans. If US nativity was a primary source for stature variation, regional economic conditions—including regional income and relative food price variations—were possible driving forces in black and white stature variation. If occupations were associated with stature variation, relative social position was a primary impetus driving black and white stature variation. If, however, insolation was a significant impetus on stature variation, part of 19th century black and white stature variation was not due to social practices or socioeconomic status but geography, and individual statures born in the South would have benefited from extended hours of direct sunlight, even though blacks born in the Deep South faced racial oppression and prejudice from whites (Higgs, 1977, p. 75). In addition, given blacks' relative inefficiency at producing vitamin D, we may expect black statures to be more responsive than white statures to the immediate effects of insolation; black statures may have increased linearly with insolation, while white statures may have increased in insolation at a decreasing rate.

[4] For how the insolation index is constructed, see Table 4 and 5 notes.

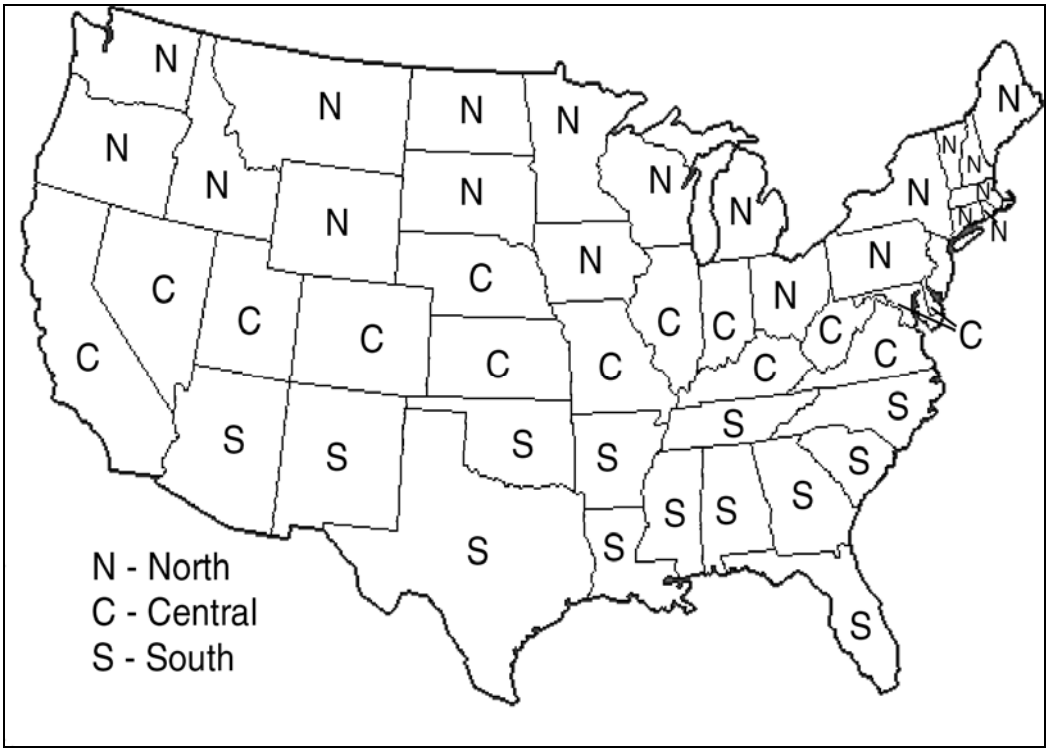


Figure 3, Geographic Regions for 19th Century Migration Patterns

To illustrate demographic, occupational and residential relationships with stature, Model 1, in both Tables 4 and 5, present youth and adult height regressions in centimeters on 10 year birth cohort dummies, dummies for occupation at the time of incarceration, nativity and migration status, with continuous values included for insolation. Migrants are typically taller than non-migrants, and because insolation is effected by migration status, migration status is controlled for in Tables 4 and 5. If insolation was a driving force in stature growth, northward moves will have adverse stature effects, and southern moves will increase stature. North1 is an intermediate move from Southern to Central or Central to Northern states. North2 is a long distance move from Southern to Northern states. South1 is a move from a Northern to Central or Central to Southern state. South2 is a move from Northern to Southern states (Figure 3).

To compare how stature varied between migrants and non-migrants, model 2 regresses stature on only those who did not migrate from their native state. Model 3 regresses stature on only white male characteristics, while model 4 does the same for blacks.

Table 4, National Youth Stature Models by Race

	Model 1, Total	*p-value*	*Model 2, Non-Migrants*	*p-value*	*Model 3, Whites*	*p-value*	*Model 4, Blacks*	*p-value*
Intercept	154.59	<.01	130.93	<.01	146.54	<.01	166.10	<.01
Race								
Black	-2.02	<.01	-2.18	<.01			Reference	
Mulatto							.676	<.01
White	Reference		Reference		Reference			
Ages								
12	-19.51	<.01	-18.69	<.01	-17.38	<.01	-20.42	<.01
13	-16.16	<.01	-16.59	<.01	-15.33	<.01	-16.46	<.01
14	-12.04	<.01	-11.65	<.01	-13.33	<.01	-11.61	<.01
15	-8.36	<.01	-8.58	<.01	-8.36	<.01	-8.46	<.01
16	-5.21	<.01	-5.15	<.01	-4.98	<.01	-5.51	<.01
17	-3.26	<.01	-3.07	<.01	-3.18	<.01	-3.38	<.01
18	-2.21	<.01	-2.00	<.01	-2.03	<.01	-2.50	<.01
19	-1.20	<.01	-1.13	<.01	-1.09	<.01	-1.41	<.01
20	-.569	<.01	-.442	<.01	-.608	<.01	-.509	<.01
21	-.216	.01	-.156	.18	-.145	.15	-.331	.03
22	-.068	.41	.009	.94	-.004	.99	-.201	.17
23	Reference		Reference		Reference		Reference	
Birth Period								
1810	.818	.01	1.48	<.01	.841	<.01	.303	.55
1820	.526	.02	.519	.12	.675	<.01	-.565	.28
1830	.067	.69	.250	.32	-.040	.82	.608	.25
1840	-.868	<.01	-.535	<.01	-.822	<.01	-1.19	<.01
1850	-.596	<.01	-.459	<.01	-.688	<.01	-.302	.04
1860	Reference		Reference		Reference		Reference	
1870	-.227	<.01	-.176	.08	-.119	.04	-.253	.05
1880	-.650	<.01	-.429	<.01	-.638	<.01	-.625	<.01
1890	-.586	<.01	-.459	<.01	-.781	<.01	-.313	.03
1900	.102	.67	.423	.18	-.447	.16	.585	.11
Occupations								
White-collar	-.345	<.01	-.387	.01	-.276	.02	-.646	.01
Skilled	-.178	<.01	-.333	<.01	-.140	.06	-.294	.08

Farmer	1.26	<.01	1.19	<.01	1.35	<.01	1.04	<.01
Unskilled	Reference		Reference		Reference		Reference	
Nativity								
Northeast	-1.90	<.01	Na		-2.05	<.01	-1.63	.01
Middle Atlantic	-1.96	<.01	-2.08	<.01	-2.25	<.01	-897	<.01
Great Lakes	-.140	.18	.319	.19	-.488	<.01	.985	<.01
Plains	Reference		Reference		Reference		Reference	
Southeast	.767	<.01	.435	<.01	.915	<.01	.770	<.01
Southwest	2.88	<.01	4.45	<.01	3.00	<.01	2.21	<.01
Far West	-.339	.08	.877	<.01	.010	.97	-.456	.02
Migration Status								
Migrant	.638	<.01			.493	<.01	.801	<.01
Persister	Reference		Reference		Reference		Reference	
Move Direction								
North1	-1.04	<.01			-1.08	<.01	-.912	<.01
North2	-1.24	<.01			-1.37	<.01	-.792	.01
South1	.248	<.01			.294	<.01	.396	.12
South2	.969	<.01			.927	<.01	1.51	.02
Hours of Direct Sunlight								
Insolation	8.72	<.01	20.62	<.01	13.13	<.01	.919	<.01
Insolation^2	-1.06	<.01	-2.57	<.01	-1.64	<.01		
N	74,582		41,969		47,507		27,075	
R^2	.1206		.1434		.1000		.1398	
F	231.73		191.43		130.53		100.25	

Source: See Table 1.

Notes: Because US historical insolation is unavailable, a modern insolation index (1993-2003) is constructed, and monthly insolation values are measured from January thru June. The insolation index measures the hours of direct sunlight per day at county centroids in each state and is weighted by a county's square miles relative to square miles

in the state.[5] While this index is a rough approximation for historical insolation, it provides sufficient detail to capture state latitudinal insolation variation and consequently, vitamin D production. The US geographic classification scheme is consistent with Carlino and Sill (2000): New England= CT, ME, MA, NH, RI and VT; Middle Atlantic= DE, DC, MD, NJ, NY, and PA; Great Lakes= IL, IN, MI, OH, and WI; Plains= IA, KS, MN, MO, NE, ND, and SD; South East= AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, and WV; South West= AZ, NM, OK, and TX; Far West= CA, CO, ID, MT, NV, OR, UT, WA, and WA.

[5] Insolation is not the insolation in the county that surround's the state's centroid, but insolation in each county's geographic center. The range of state insolation values extends from Maine's minimum of 3.43 hours of direct sunlight to Arizona's maximum of 5.22 hours of direct sunlight per day.

Table 5, Adult National Stature Models by Race

	Model 1, Total	*p-value*	*Model 2, Non-Migrants*	*p-value*	*Model 3, Whites*	*p-value*	*Model 4, Blacks*	*p-value*
Intercept	145.08	<.01	96.30	<.01	140.57	<.01	166.94	<.01
Race								
Black	-1.81	<.01	-1.98	<.01	Na		Reference	
Mulatto							.647	<.01
White	Reference		Reference		Reference			
Ages								
20s	Reference		Reference		Reference		Reference	
30s	-.010	.82	-.069	.24	-.079	.14	.199	.02
40s	-.444	<.01	-.698	<.01	-.408	<.01	-.485	<.01
50s	-.976	<.01	-.967	<.01	-.952	<.01	-.919	<.01
60s	-1.65	<.01	-1.30	<.01	-1.56	<.01	-1.65	<.01
70s	-2.39	<.01	-2.79	<.01	-2.15	<.01	-2.44	<.01
Birth Period								
1800	1.43	<.01	1.23	<.01	1.59	<.01	.198	.67
1810	1.48	<.01	1.59	<.01	1.55	<.01	.829	.02
1820	1.11	<.01	1.11	<.01	1.27	<.01	-.004	.99
1830	.295	<.01	.479	.01	.403	<.01	-.283	.18
1840	057	.40	.021	.85	.131	.09	-.225	.12
1850	-.036	.56	-.179	.06	-.145	.04	.248	.04
1860	Reference		Reference		Reference		Reference	
1870	-.306	<.01	-.330	<.01	-.380	<.01	-.181	.11
1880	-.571	<.01	-.750	<.01	-.623	<.01	-.499	<.01
1890	-.134	.33	-.191	.31	-.003	.99	-.327	.14
Occupations								
White-collar	-.247	<.01	-.442	<.01	-.145	.04	-.733	<.01
Skilled	-.292	<.01	-.420	<.01	-.210	<.01	-.579	<.01
Farmer	1.01	<.01	.852	<.01	1.13	<.01	.605	<.01
Unskilled	Reference		Reference		Reference		Reference	
Nativity								
Northeast	-.735	<.01	Na		-.958	<.01	.592	.30
Middle Atlantic	-1.25	<.01	-.039	.92	-1.44	<.01	-.744	<.01
Great Lakes	.408	<.01	1.87	<.01	.209	.05	1.06	<.01
Plains	Reference		Reference		Reference		Reference	
Southeast	1.05	<.01	1.07	<.01	1.11	<.01	1.04	<.01
Southwest	2.83	<.01	3.97	<.01	2.85	<.01	2.08	<.01
Far West	-.012	.95	.430	.13	.247	.22	-.459	.33
Migration Status								
Migrant	.330	<.01			.297	<.01	.415	<.01

Persister	Reference		Reference		Reference		Reference	
Move Direction								
North1	-.770	<.01			-.805	<.01	-.623	<.01
North2	-.598	<.01			-.380	.07	-.682	<.01
South1	.487	<.01			.436	<.01	.932	<.01
South2	1.33	<.01			1.18	<.01	1.96	<.01
Hours of Direct Sunlight								
Insolation	12.91	<.01	35.52	<.01	15.40	<.01	.692	<.01
Insolation^2	-1.44	<.01	-4.15	<.01	-1.87	<.01		
N	109,438		47,330		77,683		31,755	
R^2	.0406		.0583		.0428		.0327	
F	148.08		117.98		115.32		36.38	

Source: See Table 1.

Notes: A modern insolation index (1993-2003) is constructed for insolation, and monthly insolation values are measured from January thru June. The insolation index measures the hours of direct sunlight per day at county centroids in each state and is weighted by a county's square miles relative to square miles in the state.[6] While this index is a rough approximation for historical insolation, it provides sufficient detail to capture state latitudinal insolation variation and consequently, vitamin D production. The US geographic classification scheme is consistent with Carlino and Sill (2000): New England= CT, ME, MA, NH, RI and VT; Middle Atlantic= DE, DC, MD, NJ, NY, and PA; Great Lakes= IL, IN, MI, OH, and WI; Plains= IA, KS, MN, MO, NE, ND, and SD; South East= AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, and WV; South West= AZ, NM, OK, and TX; Far West= CA, CO, ID, MT, NV, OR, UT, WA, and WA.

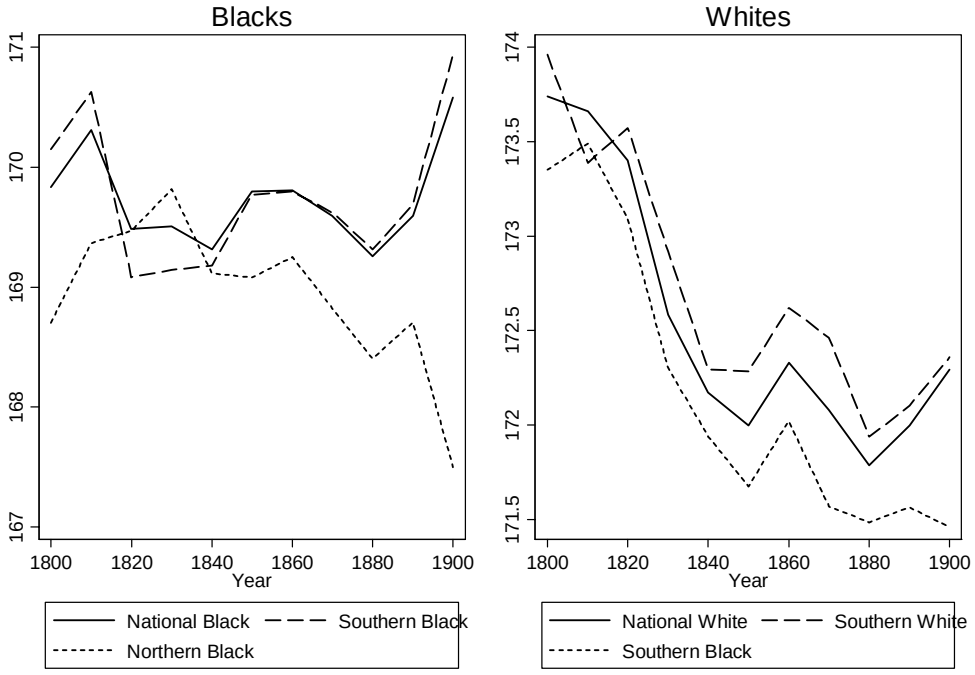
[6] Insolation is not the insolation in the county that surround's the state's centroid, but insolation in each county's geographic center. The range of state insolation values extends from Maine's minimum of 3.43 hours of direct sunlight to Arizona's maximum of 5.22 hours of direct sunlight per day.

Two general patterns emerge when comparing 19th century black and white statures. First, it is striking the degree to which white stature exceeds black stature, which is significant because modern black and white statures are comparable when brought to maturity under optimal biological conditions (Eveleth and Tanner, 1966; Tanner, 1977; Steckel, 1995, p. 1910; Barondess, Nelson and Schlaen, 1997, p. 968; Komlos and Baur, 2004, pp. 64, 69; Nelson et al., 1993, pp. 18-20; Godoy et al, 2005, pp. 472-473; Margo and Steckel, 1982, p. 519; Komlos and Lauderdale, 2005). Margo and Steckel (1982) and Sünder (2004) also demonstrate that antebellum Southern whites were nearly 2 inches taller than Southern blacks, and adult male slaves were shorter than Northern whites (Margo and Steckel, 1982, p. 519). Tables 4 and 5 demonstrate that while white prisoners were taller than black prisoners, the difference is smaller among prisoners than results reported by Margo and Steckel. Moreover, compositional effects can not explain the black-white stature differential, which was due, in part, to white's access to meat and better nutrition (Margo, and Steckel, 1982, p. 514-515, 517 and 519).

Second, the black-white stature relationships with insolation varied significantly and are consistent with the stature-insolation hypothesis. Nineteenth century black stature increased linearly with insolation, while white stature increased at a decreasing rate. Adult terminal stature is related to access to vitamin D (Xiong et al, 2005, p. 228, 230-231; X-ZLiu et al, 2003; Ginsburg, 1998; Uitterlinden et al, 2004), and vitamin D deficiency is more prevalent in geographic regions that receive fewer hours of direct sunlight (Norman, 1998, p. 1109; Holick, 1995, pp. 641S-642S). This stature-insolation relationship is consistent with other human biology studies, where darker pigmented skins were less efficient at synthesizing sunlight and cholesterol into vitamin D (Norman,

1998, pp. 1108-1110; Weisberg et al., p. 1703s; Hollick, 1995, pp. 641s-642s; Nesby-O'dell el al., 2002, p. 189). Moreover, the black stature deficit may be evidence of a previously neglected aspect of slavery's consequences on biology: the forced migration of Africans to northern climates placed blacks into biological environments in which they were not biologically suited.

Figure 4, Nineteenth Century Regional Black and White Stature by Nativity



Source: See Table 1.

Notes: African-American and white stature graphs made from national, northern and southern imputed values from Tables 4 and 5. Northern states are MN, IA, WI, MI, IL, IN, OH, PA, NJ, NY, CT, RI, MA, NH, VT, and ME. Southern states are AL, AR, FL, GA, KY, LA, MO, NC, TN, TX, and SC.

Other patterns are consistent with expectations. As reported elsewhere, mulattoes had a stature advantage over their darker black counterparts (Steckel, 1979; Bodenhorn, 1999 and 2001; Margo and Steckel, 1992, p. 511), which persists after controlling for insolation. Black and white statures varied considerably over the course of the 19th century (Figure 4). Between the 1830s and the eve of the Civil War, black adult statures increased over one cm (Komlos, 1992; Komlos and Coclanis, 1997). This supports the Komlos-Rees hypothesis that Southern overseers followed a strategy to control slave diets that maximized slaveowner wealth (Rees, 2003; Komlos, 1998; Komlos and Coclanis, 1997; Hilliard, 1972). However, once US labor markets changed from a partially slave to free labor force, black statures declined for those born in the 1880s by one-half cm. While white statures declined throughout the 19th century, black youth statures recovered by half a cm toward the end of the century (Table 4), despite economic and agricultural disruptions from the Boll Weevil and increased racial violence from whites (Higgs, 1977, p. 75).

During the 19th century, black and white statures varied by socioeconomic status, and farmers in the prison sample were consistently taller than workers in other occupations (Metzer, 1975, p. 134; Margo and Steckel, 1982, p. 525; Steckel, 1979, p. 373). Farmers traditionally had greater access to superior diets, nutrition, were outdoor occupations, and farm workers received more sunlight during adolescent ages; consequently, stature and socioeconomic status may also be related to vitamin D production. Islam et al (2007, pp. 383-388) demonstrate that children exposed to more direct sunlight produce more vitamin D, and if there was little movement away from parental occupations, 19th century occupations may also be a good indicator for the

occupational environment in which individuals came to maturity (Costa, 1993, p. 367; Margo and Steckel, 1992, p. 520; Wananamethee et al, 1996, p. 1256-1262; Nyström-Peck and Lundberg, 1995, pp. 734-737).[7] Farming is an outdoor occupation, which exposes farmers to greater direct sunlight, and 19th century farmers were taller than workers in other occupations by about one centimeter (Komlos and Coclanis, 1997, p. 441; Komlos, 1987, p. 902; Steckel and Haurin, 1994, p. 170; Sokoloff and Villaflour, 1982, p. 463; Margo and Steckel, 1983, p. 171-172). That unskilled workers were also tall suggests that many unskilled workers were agricultural workers who received abundant calorie and nutrition allocations and almost certainly worked outdoors, received more insolation, produced abundant vitamin D to reach taller terminal statures.

Black and white statures varied regionally, and after controlling for insolation, Southern blacks and whites reached the tallest statures. The opening of the New South to agriculture indicates New South agricultural productivity was higher than elsewhere in the US (Higgs, 1977, p. 24; Margo and Steckel, 1982, p. 519; Komlos and Coclanis, 1997, p. 443). Before the Civil War, the South was self-sufficient in food production and relatively high white wages may have also influenced Southern white statures (Fogel, 1994, pp. 89, 132-133). After the Civil war, although Southern wages in the West South Central were in general lower than Midwest wages, West South Central laborer's wages were comparable to those in the middle Atlantic region and limited skilled immigration into the West South Central created a relative scarcity of skilled labor, which may have been associated with high wages and better skilled Southern biological conditions

[7] Modern studies also demonstrate that rural African women who work outdoors produce more vitamin D than urban women (Nesby-Odell, 2002, p. 189).

(Rosenbloom, 2002, pp. 53, 124-125; Margo, 2000). The relative price of dairy and calcium were lowest in dairy producing regions, such as Great Lake states, but 19th century blacks were overwhelmingly native to the South, and the South was notoriously low in dairy production.[8] Northeastern blacks, especially youth, encountered adverse biological environments, and contemporary reports of rickets—a result of vitamin D deficiency—may have contributed to shorter Northeastern black and white statures (Kiple and Kiple, 1977, p. 293-294; Tortolani et al, 2002, p. 62).

4. Conclusion

This paper has identified two important patterns in 19th century black and white stature variation. First, although modern blacks and whites are more likely to come to the same stature when brought to maturity under optimal biological conditions, 19th century US blacks were ubiquitously shorter than their white counterparts. Second, part of this black stature deficit may have been partly due to blacks' forced migration to northerly latitudes were they were not biologically adapted. For example, Africans are biologically suited for optimal stature growth on or near the equator, and while it is not possible to identify each slaves' origin, African insolation is significantly greater than North American insolation. The historical record also indicates that both calcium and vitamin D were deficient in 19th century black diets (Kiple and King, 1981, p. 83), evidence of which from statures is confirmed here. Until at least the 1930s, black diets were probably vitamin D deficient, and blacks born in states that received greater insolation were taller than blacks from states that received less insolation.

[8] Southern observers at the time reported that milk was fairly abundant in border states but in short supply in the Deep South (Kiple and King, 1981, p. 83).

However, stature was also associated with nativity and occupations, indicating that regional practices, income and food price variation, and social positions were related to 19th century stature and health. Individuals from Southern states, after controlling for insolation, were taller than their counterparts born elsewhere within the US. Although varying throughout the 19th century, Southern agriculture was self-sufficient, and the South avoided the industrialization that changed the relative price of food that was deleterious to other 19th century statures. Rural farmers and unskilled workers were taller than market dependent white-collar and skilled workers. Failure to reject the stature-insolation hypothesis makes this result difficult to interpret. Farmers were undoubtedly closer to nutritious food supplies and farther from crowded urban locations, where disease was most easily propagated. However, farmers were exposed to more sunlight, produced more vitamin D than their white-collar and skilled counterparts, indicating vitamin D was significant in 19th century statures (Xiong et al, 2005, pp. 228, 230-231; X-ZLiu et al, 2003; Ginsburg et al 1998; Uitterlinden et al, 2004). That farmers were taller than workers in other occupations after regional insolation is controlled for indicates that nutritious rural agricultural diets and mild disease environments influenced farmers' statures and health. Nevertheless, rather than only sociological processes explaining the black stature deficit, part of the white stature advantage is consistent with a biologically based explanation.

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