Demographic, Residential, and Socioeconomic Effects on the Distribution of 19th Century US White Statures

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Abstract

Using a source of 19th century US state prison records, this study addresses European-American stature variation. The most commonly cited sources for stature variation are diets, disease, and work effort. However, vitamin D is also vital in human statures and health. This paper demonstrates that 19th century white statures were positively associated with direct sunlight, which is the primary source of vitamin D in mammals. Stature and insolation are associated with occupations, and workers who spent more time outdoors produced more vitamin D and grew taller. White statures also decreased throughout the 19th century, and this stature diminution is observed across the stature distribution.

JEL Code: I30, I31, J00, J15.

Keywords: 19th US white statures, vitamin D, solar radiation, quantile regression.

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Demographic, Residential, and Socioeconomic Effects on the Distribution of 19th Century United States White Stature

I. Introduction

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). By considering average versus individual stature, genetic differences are mitigated, leaving only the influences of the 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 European-Americans. Using a new source of 19th century United States prison records and robust statistics, the present study contrasts the heights of US white males across the stature distribution and adds a new explanation for traditional sources of white stature variation.

An inadequately explored source for 19th century stature variation may be related to biology, especially its relation 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, pp. 394-396; Tortolani et al, 2002, p. 60). Calcium generally comes from dairy products, and vitamin D in not dietary but is produced by the synthesis of cholesterol and sunlight in the epidermises'' stratum granulosum (Holick, 2004a, pp. 363-364; Nesby-O'dell, 2002, p. 187; Loomis, 1967, p. 501; Norman, 1998, p. 1108; Holick, 2007). Greater direct sunlight (insolation) produces more vitamin D, and vitamin D is related to adult terminal statures (Xiong et al, 2005, pp. 228, 230-231; X-ZLiu et al, 2003; Ginsburg et al 1998; Uitterlinden et al, 2004).

After the circulatory system contains sufficient amounts of vitamin D and to avoid vitamin D toxicity, vitamin D production is restricted within the stratum granulosum and residual vitamin D is broken down into inert matter (Holick et al, 1981, pp. 591-592; Jablonski, 2006, p. 62; Holick, 2001, p. 20; Holick, 2004a, p. 363). This self-limiting vitamin D effect may account for white stature variation with insolation, because at North American latitudes whites are close to the natural threshold where vitamin D production is curtailed. Moreover, to firmly establish the link between stature, insolation, and vitamin D, it is necessary to demonstrate the significance of the stature-insolation relationship across different samples and across their stature distributions. At the opposite extreme, insufficient vitamin D has been linked to rickets, osteomalasia, auto-immune diseases, and certain cancers (Holick, 2001, p. 28; Garland et al, 2006, pp. 252-256; Grant et al, 2003, p. 372).

It is against this backdrop that using robust statistics this paper addresses three paths of inquiry into 19^{th} century white stature variation in the US. First, how were insolation and vitamin D production related to white statures across the white stature distribution? This study finds that white statures were positively related with insolation and increased with insolation at a decreasing a rate. Second, how did white statures vary with occupations? White farmers were taller than workers in other occupations, and this farmer stature advantage is generally attributed to better nutrition and rural environments. However, this paper offers an additional explanation for the farmer stature advantage. Third, how did white statures vary throughout the 19th century? Results presented here illustrate that 19th century US white statures decreased throughout the 19th century, which is observed equally across the stature distribution.

II. Data

Prison Records

Table 1, Nineteenth Century US White Populations is State Prisons

Prisons	*N*	*Percent*	*Prisons*	*N*	*Percent*
Arizona	2,171	1.73	Kentucky	6,650	5.31
California	8,230	6.57	Missouri	23,787	19.00
Colorado	7,021	5.61	New Mexico	1,998	1.60
Georgia	157	.13	Ohio	24,841	19.84
Idaho	2,074	1.66	Oregon	2,040	1.63
Illinois	9,942	7.94	Pennsylvania	16,026	12.80
Kansas	4,082	3.26	Texas	16,171	12.92

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).

The data used here to study 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 whites in the sample were incarcerated in Ohio, Missouri, Texas, and Pennsylvania prisons.

All historical height data have various biases, and prison and military records are the most common sources for historical stature data. 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; A'Hearn, 2004). 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 who were drawn from lower socioeconomic groups, that segment of society most vulnerable to economic change (Bogin, 1991, p. 288; Komlos and Baten, 2004, p. 199; Nicholas and Steckel, 1991, p. 944). 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). Moreover, if—at the margins of subsistence—demographic, socioeconomic factors, and insolation were significant in stature variation, prison records may more clearly illustrate these effects.

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 and 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, occupation, 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.[1] Arrests and prosecutions across states may have resulted in various selection biases that may affect the results of this analysis. However, white stature variation within US prisons is consistent with other stature studies (Steckel, 1979; Margo and Steckel, 1982; Nicholas and Steckel, 1991, pp. 941-943; Komlos, 1992; Komlos and Coclanis, 1997; Bodenhorn, 1999; Sünder, 2004).

Fortunately, inmate enumerators were quite thorough when recording inmate complexion and occupation. For example, enumerators recorded white complexions as light, medium, dark, and fair. The white inmate complexion classification is further supported by European immigrant complexions, which were always of fair complexion and were also recorded in US prisons as light, medium, dark, and fair.[2] 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

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[1] Many inmate statures were recorded at quarter, eighth, and even sixteenth increments.

[2] 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 Irish prisons from a traditionally white population. To date, no inmate in an Irish prison has been recorded with a complexion consistent with African heritage.

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 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. Because the purpose of this study is to compare 19th century white male statures, blacks and immigrants are excluded from the analysis.

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. This 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 white statures were distributed approximately normal and there is no evidence of age heaping or arbitrary truncation points.

Table 2, Descriptive Statistics of Whites in National Prison Data

Ages	*N*	*Percent*	*Height (cms)*	*S.D. (cms)*
Teens	16,924	13.52	169.75	6.70
20s	64,187	51.27	171.95	6.52
30s	27,181	21.71	171.99	6.48
40s	10,987	8.78	171.89	6.50
50s	4,360	3.48	171.61	6.51
60s	1,318	1.05	171.25	6.73
70s	233	.19	170.94	6.42
Birth Decade				
1800	906	.72	172.41	6.50
1810	2,467	1.97	172.52	6.56
1820	4,202	3.36	172.45	6.80
1830	7,995	6.39	171.79	6.66
1840	16,541	13.21	171.46	6.52
1850	25,084	20.04	171.31	6.69
1860	25,436	20.32	171.69	6.55
1870	22,334	17.84	171.65	6.52
1880	13,075	10.44	171.69	6.50
1890	6,744	5.39	171.90	6.51
1900	406	.32	170.67	6.30
Occupations				
White-Collar	13,800	11.02	171.32	6.37
Skilled	32,196	25.72	171.28	6.38
Farmers	16,640	13.29	173.16	6.44
Unskilled	56,344	45.01	171.54	6.66
No Occupations	6,210	4.96	170.97	7.14
Nativity				
Northeast	4,030	3.22	170.70	6.31
Middle Atlantic	32,335	25.83	170.09	6.36
Great Lakes	32,629	26.06	171.88	6.42
Plains	17,839	14.25	171.94	6.38
Southeast	21,857	17.46	172.91	6.66
Southwest	10,708	8.55	173.39	6.84
Far West	5,792	4.63	170.62	6.60
Decade Received				
1820s	13	.01	168.52	5.29
1830s	958	.77	171.56	6.47
1840s	1,859	1.48	171.80	7.08
1850s	3,683	2.94	172.4	6.69
1860s	9,637	7.70	170.99	6.68
1870s	20,557	16.42	171.48	6.73
1880s	22,108	17.66	171.70	6.66
1890s	18,691	22.92	171.70	6.46
1900s	19,889	15.89	171.50	6.50

1910s	17,325	13.84	171.96	6.42
1920s	470	.38	172.38	6.45

Source: See table 1.

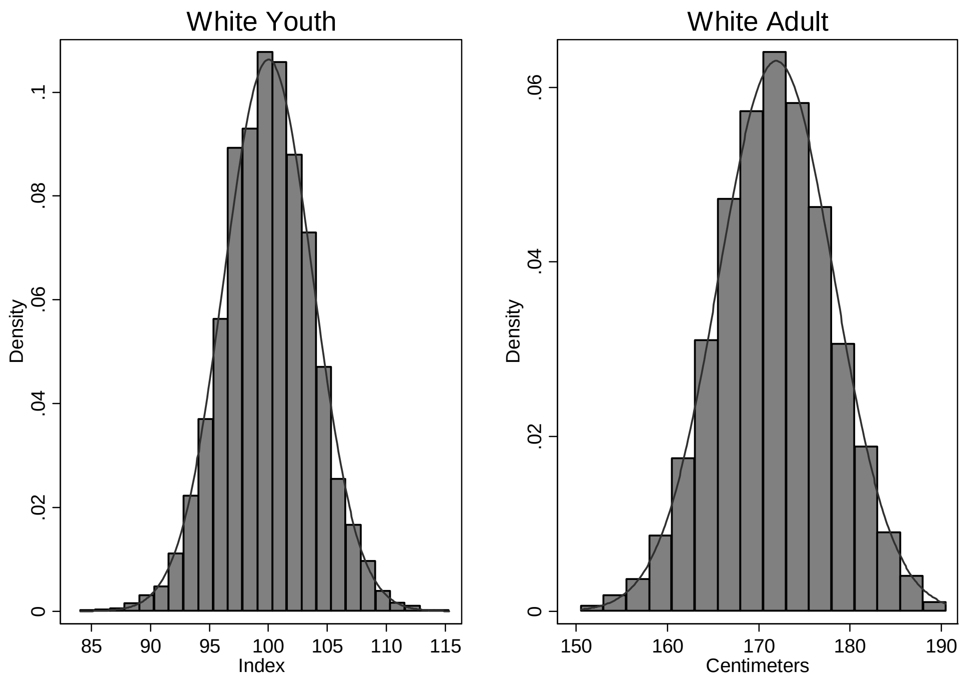

Figure 1, Nineteenth Century US White Stature Distributions

Source: See Table 1.

Table 2 presents proportions for white inmates' age, birth decade, occupations, and nativity. Although average statures are included, they are not reliable because of possible compositional effects, which are accounted for in the regression models that follow. Age percentages demonstrate that whites were incarcerated at older ages. Most prisoners were born in the mid-19th century; occupations reflect socioeconomic status, and while prison inmates typically come from lower working classes, there was a sizeable share of inmates from white-collar and skilled occupations. Most whites in the sample were born in the Middle-Atlantic and Great Lakes states; the South and Far-west are also represented in the sample.

United States' Insolation

To account for the relationship between vitamin D and stature, a measure is constructed that accounts for solar radiation. Insolation is the incoming direct sunlight that reaches the earth, its atmosphere, and surface objects.[3] Insolation is also the primary source of vitamin D (Holick, 1991, p. 590; Holick, 2007, p. 270). Because of its distance from the equator, Europeans were efficient in vitamin D production at low insolation latitudes in the Northern hemisphere. As early hominids migrated out of African to Northern latitudes, they received less solar radiation, and through the process of natural selection, darker pigmented hominids were less successful hunter-gatherers in Northern latitudes and were selected-out (Loomis, 1967, pp. 503-504).

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[3] Insolation is an acronym for incident solar radiation, and is a measure for sunlight energy received for a given surface area at a given time. If w equals watts, m equals meters, and i equals insolation,

$$i = \frac{w}{m^2} = \frac{kwh}{m^2 \cdot day}.$$

Because US historical insolation is unavailable, a modern insolation index (1993-2003) is constructed, and monthly insolation values are measured from January through June. The insolation index measures statewide average insolation levels across each of the states based on the hours of direct sunlight received per day at county centroids in each state.[4] Each state estimate is then determined by summing the average hours of direct sunlight for each county (at its centroid), weighted by the proportion of the county's total land area (in square miles) to the state's total land area (in square miles). 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. Predictably, Southern states have greater insolation than Northern states. For example, Texas receives 1.43, or 29 percent, more hours of direct sunlight per day than New York. It is also difficult to interpret insolation's net direct effect on human health, because greater insolation reduces calories required to maintain body temperature and produces more vitamin D, but greater insolation also warms surface temperatures, which may have made disease environments less healthy from water-borne diseases, especially in the South.

III. Socioeconomic Status, Geography, Insolation, and White Stature

Nineteenth century white statures were related to age, socioeconomic status, birth cohorts, and nativity; they may have also been related to insolation and vitamin D production. Which of these factors dominates reveals much about conditions facing 19th

[4] Insolation is not the insolation in the county that surrounds 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.

century whites. If US white nativity was a source for stature variation, regional diets and social practices were a possible driving force in stature variation. If occupations were associated with stature, relative social position was a primary impetus driving white stature variation. If, however, insolation was a significant impetus on white stature, part of 19th century white stature variation was not due to social or cultural factors but also geographical, and whites born in the South would have benefited from extended exposure to insolation.

To better understand the interaction between the conditional stature distribution and socioeconomic and demographic characteristics, a stature quantile regression function is constructed. Let s_i represent the stature of the i^{th} inmate and x_i the vector of covariates for birth cohort, socioeconomic status, and demographic characteristics. The conditional quantile function is

$$s_i = Q_y\left(p|x\right) = \theta x + \eta S\left(p\right),\ p \in \left(0,1\right)$$

which is the p^{th}-quantile of s, given x.[5] The interpretation of the coefficient θ_i is the influence of the i^{th} covariate on the stature distribution at the p^{th} quantile. For example, the age coefficient at the median (.5 quantile) is the stature increase that keeps an "average" inmate's stature on the median if age increases by one year. When estimating stature regressions, quantile estimation offers several advantages over least squares. Two advantages in anthropometric research are more robust estimation in the face of an unknown truncation point and greater description of covariate effects across that stature distribution.

[5] The coefficient vector θ is obtained using techniques presented in Koenker and Bassett (1978 and 1982) and Hendricks and Koenker (1992).

We test which variables were associated with the height of 19th century whites. To start, stature for the i th individual is related to age, socioeconomic status, birth period, nativity, and insolation.

$$Cent_i = \alpha + \beta_1^p Black_i + \sum_{a=12}^{70} \beta_a^p Age_i + \sum_{t=1}^{10} \beta_t^p Birth\,Decade_i + \sum_{l=1}^{3} \beta_l^p Occupation_i$$

$$+ \sum_{n=1}^{6} \beta_n^p Nativity_i + \beta_{Migration}^p Migration_i + \sum_{d=1}^{4} \beta_d^p Move\,Direction_i + \beta_{Insol}^p Insolation_i$$

$$+ \beta_{Insol^2}^p Insolatiion_i^2 + \varepsilon_i^p$$

Dummy variables are included for individual youth ages 12 through 22; adult age dummies are included for ten year age intervals from the 40s through the 70s. Birth decade dummies are in ten year intervals from 1800 through 1899. Occupation dummy variables are for white-collar, skilled, farmers, and unskilled occupations. Nativity dummy variables are included for birth in Northeast, Middle Atlantic, Great Lakes, Southeast, Southwest, and Far West regions. A dummy variable accounts for migration status and directional migration dummy variables are included to account for North-South migrations.[6] If insolation was a driving force in stature growth, northward moves

[6] 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. Northern states include Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Michigan, Wisconsin, Iowa, Minnesota, North Dakota, South Dakota, Wyoming, Montana, Idaho, Oregon, and Washington. Central states include Delaware, Maryland, Virginia, Wes Virginia, Kentucky, Indiana, Illinois, Missouri, Nebraska, Kansas, Colorado, Utah, Nevada, and California. Southern states include North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, Texas, New Mexico, and Arizona. The binary variable North1

will have adverse stature effects, and southward moves will be associated with taller statures. Continuous insolation and insolation difference variables between receiving and sending locations are added to account for insolation and vitamin D production.

Table 3's model 1 presents least squares estimates for the white sample. To illustrate how white stature was related to demographic, occupation, nativity, migration, and insolation across the stature distribution, models 2 through 6 present .25, .50, .75, .90, and .95 quantile stature estimates.

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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.

Table 3, Nineteenth Century United States National Quantile Stature Models related to Demographics, Birth Period, Migration, and Insolation by Socioeconomic Status

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
	OLS	*.25*	*.50*	*.75*	*.90*	*.95*
Intercept	143.43***	135.27***	143.74***	153.24***	155.80***	169.44***
Ages						
12	-17.35***	-21.16***	-16.48***	-13.80***	-10.30***	-10.02***
13	-15.26***	-17.99***	-15.85***	-10.37***	-8.79***	-6.83***
14	-13.27***	-13.42***	-13.45***	-12.49***	-11.77***	-10.15***
15	-8.31***	-8.50***	-8.35***	-8.04***	-6.81***	-5.88***
16	-4.90***	-4.80***	-5.04***	-5.09***	-5.35***	-5.50***
17	-3.13***	-2.86***	-3.08***	-3.29***	-3.14***	-3.46***
18	-2.00***	-1.81***	-2.11***	-2.28***	-2.30***	-2.21***
19	-1.06***	-.916***	-1.04***	-1.23***	-1.36***	-1.39***
20	-.586***	-.596***	-.528*	-.606***	-.778***	-.651**
21	-.146***	-.088	-.141*	-.160*	-.169*	-.231*
22	-.001**	.021	-.005	.043	-.001	.158
23-39	Reference	Reference	Reference	Reference	Reference	Reference
40s	-.333***	-.228***	-.444***	-.486***	-.214*	-.334***
50s	-.842***	-.786***	-.864***	-.843***	-.711***	-.778***
60s	-1.43***	-1.68***	-1.66***	-1.28***	-1.36***	-858**
70s	-2.03***	-1.97***	-2.28***	-2.07***	-1.98***	-.904*
Birth Decade						
1800s	1.52***	1.66***	1.76***	1.76***	1.02***	.836
1810s	1.43***	1.73***	1.46***	1.50***	1.14***	1.04**
1820s	1.13***	1.03***	1.12***	.328***	1.32***	1.58***
1830s	.287***	.259*	.216**	.328**	.321*	.379**
1840s	-.124**	-.085	-.186***	-.195***	-.169	-3.9^{-7}
1850s	-.317***	-.368***	-.294***	-.309	-.350***	-.184*
1860s	Reference	Reference	Reference	Reference	Reference	Reference
1870s	-.260***	-.085	-.405***	-.309***	-.299***	-.221***
1880s	-.584***	-.364***	-.714**	-.681***	-.661***	-.680***
1890s	-.411***	-.330**	-.510***	-.222*	-.366**	-.333
1900s	-.170	-.175	-.206	.010	-.732***	-.935**
Occupations						
White-Collar	-.178***	-.053	-.184**	-.263***	-.450***	-.356***
Skilled	-.192***	-.053	-.195***	-.264***	-.407***	-.405***
Farmer	1.21***	1.31***	1.15***	1.17***	.997***	.953***
Unskilled	Reference	Reference	Reference	Reference	Reference	Reference
Nativity						
Northeast	-1.46***	-1.21***	-1.61***	-1.49***	-1.73***	-2.12***

Middle Atlantic	-1.78***	-1.61***	-1.88***	-1.87***	-1.89***	-2.36***
Great Lakes	-.095	.066	-.207***	-.145***	8.7^{-4}***	-.249***
Plains	Reference	Reference	Reference	Reference	Reference	Reference
Southeast	.954***	.881***	.930***	1.10**	1.12***	.850***
Southwest	2.87***	2.78***	2.93***	2.84***	3.23***	3.19***
Far west	.193	.329*	.224	.051	.028	-.202
Migration Status						
Migrant	.284***	.194***	.266***	.392***	.314***	.292***
Non-migrant	Reference	Reference	Reference	Reference	Reference	Reference
Move Direction						
North1	-.733***	-.609***	-.689***	-.830***	-.785***	-.615***
North2	-.333*	-.137	-.320***	-.542***	-.498*	-.087
South1	.221***	.124	.235***	.302***	.190***	.318*
South2	.734***	.379	.606***	1.08***	1.29***	1.76***
Insolation Variables						
Insolation	14.23***	15.96***	14.26***	11.43***	12.08***	6.91**
Insolation^2	-1.75***	-1.94***	-1.77***	-1.40***	-1.48***	-.891**
Insolation Difference	.322***	.563***	.260***	.155**	.168*	-2.6^{-7}
N	125,190	125,190	125,190	125,190	125,190	125,190
R^2	.0677	.0328	.0345	.0345	.0340	.0340

Source: See Table 1.

Notes: *-1 percent significant; **-5 percent significant; ***-10 percent significant.

Standard errors attained with bootstrap.

Three general patterns emerge when assessing 19th century white statures. First, consistent with the bio-medical explanation, for each additional hour of direct sunlight, whites reached about one centimeter taller statures (Holick et at, 1981, pp. 590-591; Jablonski, 2006, p. 62; Holick, 2004a, p. 363; Holick, 2004b, p. 1680S; Carson, EEH, forthcoming). Moreover, white statures increased with insolation at a decreasing rate, indicating there is a natural threshold to the amount of vitamin D produced internally, and whites in North American latitudes were at the threshold where vitamin D production is curtailed (Holick et al, 1981, pp. 590-591; Jablanski, 2006, p. 62; Holick, 2004a, p. 363; Holick, 2004b, p. 1680S). Tests for insolation's affect across the stature distribution demonstrate that the amount of sunlight was positively associated with stature, and whites in lower stature quantiles received larger stature returns from insolation than whites in higher stature quantiles (Koenker, 2005, pp. 75-76; Koenker and Bassett 1982). Furthermore, the positive coefficient on the insolation difference variable between sending and receiving locations indicates that for each additional hour of sunlight associated with a migration, white migrants were about one-half cms taller than non-migrants. Therefore, insolation and vitamin D probably influenced 19th century white statures, which is supported by modern population studies (Norman, 1998, pp. 1108-1110; Holick, 1995, pp. 641s-642s; Nesby-O'Dell et al, 2002, p. 189).

Second, 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). Moreover, tests for occupational affects illustrate that farmers in lower quantiles received greater stature returns from insolation than workers in higher stature quantiles. Farmers traditionally had greater access to superior diets and nutrition, but farmers also worked outdoors and were exposed to more sunlight during adolescent ages; consequently, stature and socioeconomic status may also be related to vitamin D production (Bodiwala et al, 2003, pp. 659-660; Tangpricha et al, 2002, p. 662). Islam et al (2007, pp. 383-388) demonstrate that children exposed to more insolation 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 come to maturity (Costa, 1993, p. 367; Margo and Steckel, 1992, p. 520; Wananamethee et al, 1996, pp. 1256-1262; Nyström-Peck and Lundberg, 1995, pp.734-737). That unskilled workers were also tall suggests that many unskilled workers were agricultural workers, who received sufficient nutrition allocations and almost certainly worked outdoors, received more insolation and produced sufficient vitamin D to reach taller statures.

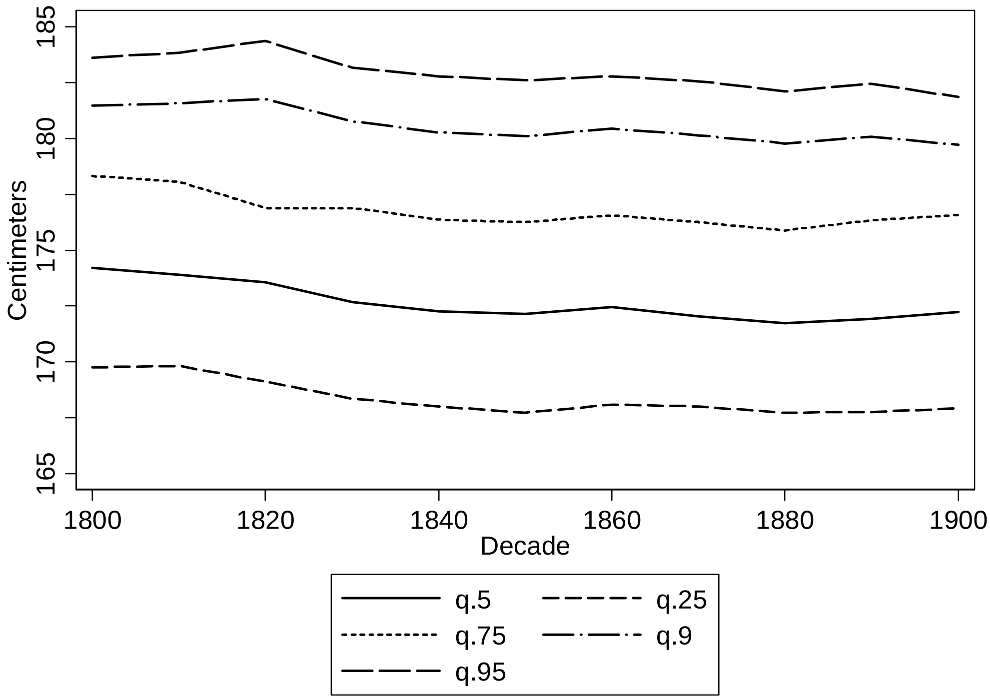

Figure 2, Nineteenth Century US Whites across Quantiles

Source: See Table 3.

Third, white statures decreased throughout the 19th century, and this is observed across the stature distribution. Between 1800 and 1900 and across quantiles, statures declined by nearly 2 cms (Figure 2). Part of the stature decline corresponded with US industrialization and urbanization. Nineteenth century US agricultural commercialization separated producers from consumers. During the early 19th century, white farmers worked in rural agricultural environments, and the rise of Northeastern urban centers—such as New York City, Boston, and Philadelphia—placed disproportionate stress on rural farmers who lived near urban centers (Carson, 2008b, pp. 367-368). For example, although Southeastern Pennsylvanian's were in close physical proximity to leading

Bucks, Chester, and Lancaster counties, they were also closer to urbanized Philadelphia, and Southeastern Pennsylvanian's reached shorter terminal statures than individuals from rural Pennsylvania (Carson, 2008b, pp. 363-368; Cuff, 2005, pp. 154-161). Urbanization and industrialization created other costs related with agricultural commercialization. Industrialization's proliferation compromised the quality of dairy and meat production, and in this pre-refrigeration period, food spoilage increased as the distance between rural farms and urban centers increased (Craig et al., 2004).

Other relationships are consistent with expectations. Statures varied regionally, and Southwestern whites reached the tallest statures. Internal immigrants who located southward were taller than those who immigrated northward, and Southern white stature gains were larger than those experienced by Northern whites. Part of the Southern migration advantage was related to Southern agriculture. The 19th century opening of the South to agriculture increased Southwestern agricultural productivity, which 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 white Southern statures (Fogel, 1994, pp. 89, 132-133). After the Civil War, Southern wages in the West South Central were in general lower than Midwest wages and were comparable to those in the Middle Atlantic region. Northeasterners, especially youth, encountered adverse biological environments, and contemporary reports of rickets—a result of vitamin D deficiency—may have contributed to shorter Northeastern statures.

IV. Conclusions

This paper demonstrates that insolation was an important source of 19th century white stature variation and illustrates that whites at North American latitudes were closer to the biological threshold were vitamin D production is curtailed. Moreover, to establish the link between stature, insolation, and vitamin D, a positive and significant relationship between insolation and stature is observed across the stature distribution. The stature-insolation hypothesis also adds to our knowledge for why 19th century farmers were taller than workers in other occupations. Farmers were closer to nutritious food supplies and further from urban locations, where disease was most easily spread. However, farmers also worked outdoors, were exposed to more sunlight, produced more vitamin D than their white-collar and skilled counterparts, and reached taller terminal statures. White statures declined throughout the 19th century, a pattern frequently observed with industrialization and urbanization. Therefore, 19th century statures were associated with a complex set of demographic, environmental, and occupational factors, which were consistently related with US white statures across the stature distribution.

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