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Abstract

Individuals urbanize when the net benefits to urbanization exceed rural living conditions. Body mass, height, and weight are welfare measures that reflect the net difference between calories consumed and calories required for work and to withstand the physical environment. Nineteenth and early 20th century US urban residents had lower BMIs, were shorter, with lower weights than rural residents. Urban net nutrition varied by race, and urban whites and blacks had lower BMIs, shorter statures, and lower weights compared to their rural counterparts. Urban male net nutrition experienced greater variation than urban females, and urban females may not have been affected as much as males by urbanization.

JEL-Codes: C100, C400, D100, I100, N300.

Keywords: urbanization, stature variation, cumulative net nutrition, nativity, race.

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I. Introduction

Populations urbanize when the difference between the sum of net discounted urban and rural living standards exceed migration costs (Sjaastad, 1962; Bogin, 2001, pp. 189-228; Meinzer et al. 2019, pp. 232-244), and throughout economic development, economic opportunity varies between urban and rural areas. Urbanization is also related to material conditions and resource allocation, both within the economy and within the household (Bogin, 2001, p. 255), and a common difficulty when measuring urban welfare is an agreeable measure that reflects material conditions. Income and wealth are two standard material welfare measures, however, exclude non-priced characteristics, such as pollution, medical innovations, and the relative price of food (Nordhaus, 2003, p. 20; Gordon, 2015). Biological measures that reflect material and net nutrition are alternatives to income and wealth. For example, a population's average stature, body mass, and weight reflect material welfare that are complements to income and wealth, and vary during urbanization between gender and race. Body mass and weight reflect a population's current net nutrition, and a population's average stature measures the cumulative difference between calories consumed and calories required for physical activity and the demands of the physical environment. Subsequently, body mass, height, and weight vary between urban locations by gender and race both within the household and across a developing economy (Zhehetmeyer, 2010; Floud et al, 2011, pp. 35 and 160).

United States agriculture, transportation, and economic production varied between 1870 and 1940, and before the Civil War, agricultural production was limited to small-scale family farms (Atack and Bateman, 1987, pp. 201-224; Cochrane, 1979, pp. 21-32). During economic development within the household, males are disproportionately in physically active occupations,

and receive greater calories per day than women (Bogin, 2001, p. 255; Gordon, 2015, p. 75), and time is long-past when studying household resource allocation can be assumed to be equally distributed within the household (Oren, 1973, pp. 107-111). British working-class women consumed small shares of 19th century income, nutrition, and medical care (Oren, 1973, pp. 107-111), and this inequality involved diets and protein consumption. For example, during the 19th century, male household heads consumed 3,685 calories, which exceeded female calories by 1,000 calories (Gordon, 2015, p. 75; Carson, 2023). Furthermore, women received different treatment in their roles as mothers (Jennings, 1992, p. 134). Males were more physically active and taller because of sexual dimorphism, and both were related to calorie allocation within the household (Oren, 1973, pp. 109-111).

During early US economic development, legal institutions were not favorable toward women, and there were various periods when women's rights progressed, then abated. The 1848 Seneca Falls convention was an early US women's rights convention that advocated women's suffrage; however, because of its immediacy, ending US chattel slavery took precedent over women's suffrage. After emancipation, women's suffrage resumed, and by 1872, Virginia Miner—an early Missouri suffragette—pressed for female voting rights in a Saint Louis County election was, however, denied by the Missouri State Supreme Court because of her gender. Undeterred in 1874, Miner appealed to the US Supreme Court, where she was again denied, when the Court upheld that the US does not grant suffrage with citizenship. After a generation's effort, by 1920, the 19th Amendment was ratified, giving women voting rights and realigned bargaining power within the household and larger economy. As a result, net nutrition varied by race, gender, and stature related to 19th century urban status.

It is against this backdrop that this study considers three questions regarding 19th century urbanization, gender, and race. First, what was the compensating net nutritional differential for individuals who lived in urban and rural areas during the late 19th and early 20th century? Nineteenth and early 20th century urban US residents had lower BMIs, shorter statures, and lower weight than rural residents, indicating that urban residents accepted lower net nutrition for economic opportunity. Second, what were the current and cumulative urban net nutritional differences between males and females? Results are mixed by urban gender, and women's body mass was unaffected, while urban males had lower BMIs, shorter statures, and lower weights compared to rural males. Third, what were urban and rural net nutrition differences by race? Urban material and nutrition conditions varied by race, and both urban whites and blacks had lower BMIs, shorter statures, and lower weight.

II. Nineteenth Century United States Urbanization

Health and nutrition vary with urbanization, and while there are urban benefits, greater population density increases the relative price of nutrition, separates food production from consumption, and increases disease burdens (Bogin, 2001, pp. 250-251 Carson, 2020; Carson, 2022). Greater population concentrations increase infectious disease rates, which are inversely related to stature and body mass (Craig, Weiss, and Haines, 2003; Floud et al. 2011; Carson, 2020; Carson, 2022). Rural residents were taller and show urbanization's long-standing adverse effects on health (Steckel and Rose, 2002, p. 575). Urbanization considered here is classified into two groups: large and small urban centers. Through 1790, Philadelphia was the first large US population center. By 1840, New York City's population reached 300,000, and 19th century US urbanization was local to the Northeast, and early 19th century US urbanization began along its eastern seaboard (Gordon, 2015, p. 35). In 1870, 25 percent of the US population was

urbanized (Hanes, 2000, p. 156, Table 4.2; Gordon, 2015, p. 94). By 1940, urbanization's net benefits increased, and 57 percent of the US population urbanized (Haines, 2000, p. 156. Table 4.2; Gordon, 2015, pp. 94-99). Chicago's population began later but surpassed Philadelphia's population by 1860, and Chicago, Philadelphia, and Saint Louis are three large 19th and 20th century urban centers included in this study. Early urban populations remained North because of disease, and only two of the most populated 19th century urban cities were in the South. By 1930, Saint Louis was the fourth largest population center, followed by Pittsburgh (Figure 1).

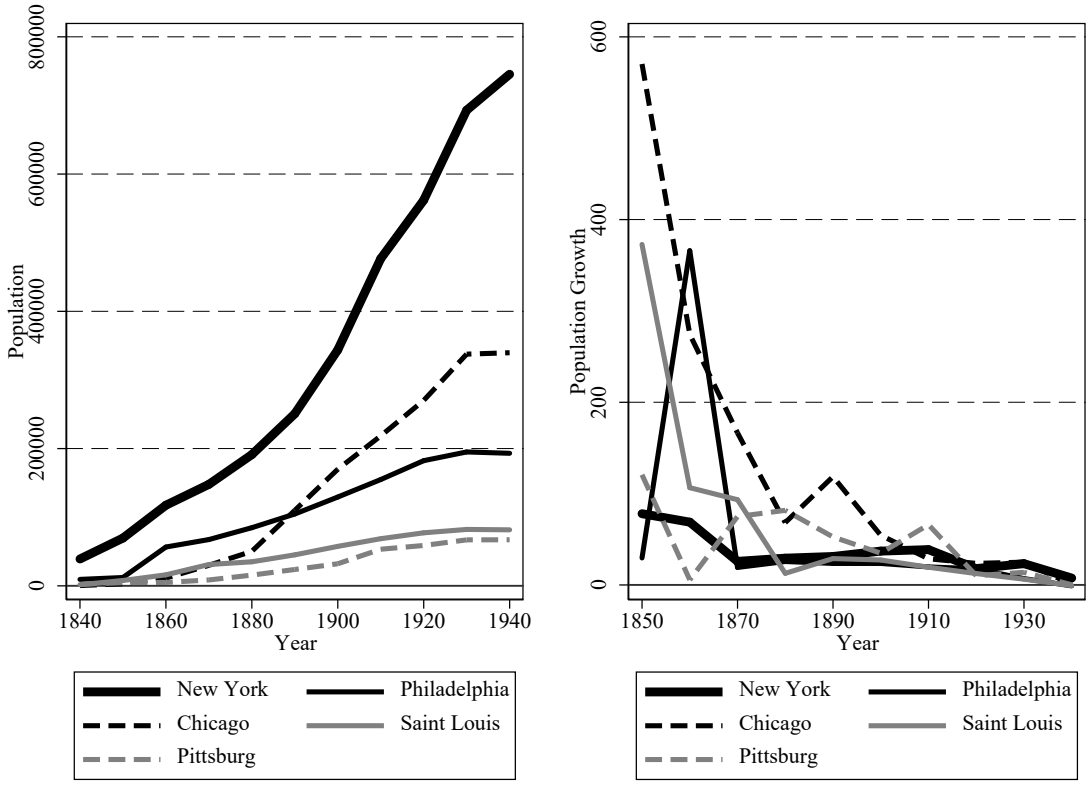

Figure 1, Large Late 19th and Early 20th Century Urban Centers: Chicago, Saint Louis, Philadelphia, Pittsburgh, and New York

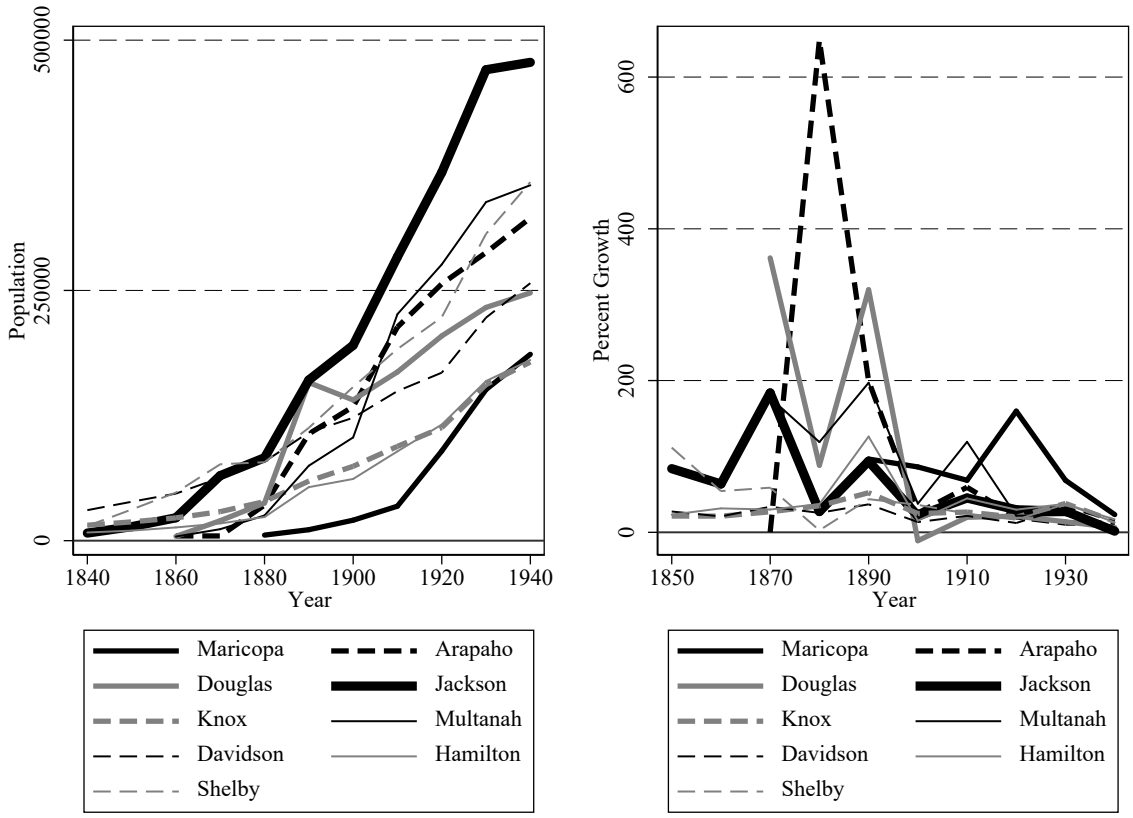

Figure 2, Small Late 19th and Early 20th Century Growing Urban Centers: Maracopa (Phoenix), Arapaho (Denver), Douglas (Omaha), Multanah (Portland), Davidson (Nashville), Hamilton (Chattanooga), and Shelby (Memphis)

There were smaller urbanizing centers, and smaller 19th century urbanizing communities considered here include Alleghany (PA), Davidson (TN), Arapaho (CO), Douglas (NE), Hamilton (TN), Jackson (MO), Knox (TN), Mairopa (AZ), Multanah (OR), and Shelby (TN). Populations grew at diverse rates, but small urban location levels were similar (Figure 2). Like larger urban areas, small US urban growth rates started high and converged over time to lower growth rates.

Table 1, Comparison of 19th and 20th Century Urban Net Nutrition Studies

Study	*Period*	*Population*	*Results*
Komlos,1987, pp. 904-905.	19th Century United States	New York Cadets	Urban did better than rural residents in the 1830s and 1840. By the 1870s, urban residents were taller than rural.
Voth and Leunig, 1996, p. 559	1770-1873	Marine Society, Industrial Revolution	London, smallpox reduced height
Haines, Craig, and Weiss, 2003. P. 406.	1830 to 1860	United States Army recruits	Urban male heights were between 1.16 and 1.22 shorter than rural males.
Hiermeyer, 2010,	19th Century	United States West Point Cadets	Urban male heights between .1 and .12 centimeters shorter than rural male heights.
Zehetmayer, 2011	1847-1894	United States Army recruits	Urban male heights between .21 and .34 centimeters shorter than rural heights.
Zehetmayer, 2013	1847-1894	United States Army recruits	Urban heights are positively related to railroad network size, manufacturing real wages, and socioeconomic status. Urban heights are negatively related to death rate and a city's percent

			manufacturing employment.
Bailey et al. (2018).	1892-1897	British Service Records	Strong inverse relationship between coal use intensity and British height.
Meinzer et al, 2019, pp. 232-244	Antiquity to Early Modern Europe	6000 European Skeletons	North American inverse stature relationship with urbanization before Columbia contact.

Sources: Komlos (1987). **"**The Height and Weight of West Point Cadets."; Voth and Leunig. "Did Small Pox Reduce Height."; Haines, Craig, and Weiss. "The Short and the Dead."; Hiermeyer. (2010). "The Height and BMI Values of West Point Cadets."; Zehetmayer. (2013). "Health , Market Integration, and the Urban Height Penalty."; Bailey, Hatton, and Inwood. (2018). "Atmospheric Pollution, Health, and Height in Late Nineteenth Century Britain."; Meinzer, Steckel, and Baten. (2018). "Agricultural Specialization, Urbanization, Workload, and Stature."

Various studies address the relationship between urbanization and net nutrition, and a few trends are clear. Urban statures were mostly shorter than rural statures, and statures decreased throughout much of the 19th century (Table 1). Less is known, however, about 19th century urban net nutrition variation by gender and race.

III. Urban and Rural Body Mass, Height, and Weight Data

Data to examine early US economic industrialization and urbanization is part of an extended effort to collect and collate 19th and early 20th century US prison records. Ideally, institutions and processes would have collected random samples to evaluate urban health. These data are, unfortunately, not available. Military and prison records are two common sources used to evaluate net nutritional conditions, and military records were the first large-scale source

uncovered and used to evaluate 19th century statures and net nutrition (Fogel et al 1978; and Fogel at 1979). Military records primarily include males of European descent, and military recruitment standards may have been related to economic conditions and military needs at the time. Prison records are a second data source used in net nutrition studies for individuals not represented in military records, such as women and minorities. Like military records, prison records have advantages and limitations, and prison records are more likely to include women and racial minorities. Prison records are not, however, above scrutiny, and prison records may include individuals from lower socioeconomic groups. However, lower socioeconomic groups were net nutritionally at the margins, and their biological variation may provide valuable insights into net nutrition.

Physical characteristics were recorded at the time individuals were incarcerated and reflect pre-incarceration conditions. Gender, race, nativity, pre-incarceration occupation, birthplace, height, weight, and crime were recorded by prison enumerators at the time of incarceration. Gender and race were two leading characteristics enumerated by prison officials, and there are 4,592 women and 180,142 men recorded in prison records received between 1840 and 1944, making US state prison records a valuable source to evaluate female and male net nutritional conditions. Women are about 2.5 percent of the prison population. There are 46,804 individuals recorded in urban locations, and 137,930 recorded rural locations, indicating that like the general population, 25 percent of the prison population was urban (Gordon, 2015).

Race is inferred from a complexion category recorded on entry and enumerators used six complexion categories to classify complexion: white, black, mulatto, Asian, Mexican, and various indigenous groups. Individuals of European descent are the most common group and were recorded as white, light, medium, and dark. Individuals of African ancestry were recorded

as negro, light, medium, and dark black. This complexion scheme is supported further because individuals of European descent are classified as white, light, medium, and dark in US prisons who claimed nativities from Great Britain and Europe—two geographic regions with high white representation. There were also individuals of combined European and African ancestry recorded in prison records as 'mulatto.' However, in the results that follow, individuals of combined European and African ancestry are classified as 'mixed-race.' At least for a time, the Arizona and Montana prisons recorded both written descriptions and photographs with complexion classification, and it is clear from these records that individuals were classified with accurate European and African classification. Mestizos, or individuals of combined European and Native Mexican populations, are classified as Mexicans. There are also Asian populations who were from China, Japan, and Korea classified as Asian. There were Indigenous American inmates from tribal groups, such as Hopi, Apache, and Sioux.

Table 2, Urban and Rural Late 19th and Early 20th century Characteristics

	Urban		*Rural*	
	N	Percent	N	Percent
Gender				
Female	1,273	2.72	3,319	2.41
Male	45,524	97.28	134,611	97.59
Ages				
Teens	5,904	12.61	20,205	14.65
20s	23,464	50.14	69,350	50.28
30s	10,619	22.69	29,001	21.03
40s	4,460	9.53	12,244	8.88
50s	1,733	3.70	5,099	3.70
60s	514	1.10	1,695	1.23
70s	92	.20	301	.22
80s	11	.02	35	.03
Occupations				
White-Collar, Skilled	17,163	36.68	36,850	26.72
Unskilled	16,495	35.25	83,572	60.59
No Occupations	13,139	28.08	17,508	12.69
Ethnicity				

Native American	13	.03	312	.23
Asian	13	.03	89	.06
Black	10,225	21.85	31,402	22.77
Mexican	65	.14	6,670	4.84
Mixed-Race	8,024	17.15	19,430	14.09
White	28,457	60.81	80,027	58.02
Nativity				
International				
Africa	24	.05	50	.04
Asia	144	.31	269	.20
Australia	26	.06	108	.08
Canada	444	.95	1,312	.95
Europe	3,774	8.06	6,369	4.62
Great Britain	2,167	4.63	3,904	2.83
Latin America	99	.21	276	.20
Mexico	455	.97	5,980	4.34
National				
Far West	720	1.54	4,081	2.96
Great Lakes	5,037	10.76	11,563	8.38
Middle Atlantic	11,270	24.08	14,187	10.29
Northeast	620	1.32	1,633	1.18
Plains	5,393	11.52	16,283	11.81
Southeast	15,854	33.88	43,346	31.43
Southwest	770	1.65	28,569	20.71
Residence				
Arizona	881	1.88	3,231	2.34
Colorado	1,929	4.12	4,159	3.02
Idaho			699	.51
Illinois	7,714	16.48	4,174	3.03
Kentucky			13,090	9.49
Missouri	4,096	8.75	15,711	11.39
Mississippi			1,737	1.26
Montana			9,380	6.80
Nebraska	2,802	5.99	5,572	4.04
New Mexico			3,185	2.31
Oregon	741	1.58	1,664	1.21
PA, East	3,716	7.94	5,521	4.00
PA, West	2,046	4.37	5,858	4.25
Philadelphia	8,725	18.64	377	.27
Tennessee	14,147	30.23	15,225	11.04
Texas			44,149	32.01
Utah			3,667	2.66
Washington			531	.38
Counties				
Allegheny	2,100	1.14		
Cook	7,511	4.07		

Davidson	3,677	1.99		
Denver	1,929	1.04		
Douglas	2,759	1.49		
Hamilton	2,017	1.09		
Jackson	2,836	1.54		
Knox	1,854	1.00		
Maricopa	881	.48		
Multanah	737	.40		
Philadelphia	12,386	6.70		
Saint Louis	2,969	1.61		
Shelby	6,821	3.69		
Rural	136,250	73.75		
Decade Received				
1840s			233	.17
1850s			1,195	.87
1860s	333	.71	2,286	1.66
1870s	3,514	7.51	11,563	8.38
1880s	8,161	17.44	19,357	14.03
1890s	8,693	18.58	27,532	19.96
1900s	11,683	24.97	36,483	26.45
1910s	10,320	22.05	33,225	24.09
1920s	3,026	6.47	3,482	2.52
1930s	839	1.79	1,971	1.43
1940s	228	.49	603	.44

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; Maryland State Archives, 350 Rowe Building, Annapolis, MD 21401; 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, OH43211; 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.

Prison data are reported for the proportion of urban-rural by characteristics (Table 2). Socioeconomic status is categorized by occupations, which are classified as skilled and white collar, unskilled, and workers with no occupation. Although prison records mostly consist of unskilled and workers without occupations, there is a large share of the late 19th and early 20th century US prison populations classified as white-collar and skilled (Rosenbloom, 2002, p. 88; Church et al 2011; Gordon, 2015, p. 53, Table 2 and Table 3). Nineteenth century farmers had greater income and wealth (Soltow, 1975; Ferrie, 1999), which contributed to less criminal participation, and farmers took up a small proportion of prison occupations and are excluded because women were not farmers. Male skilled and white-collar workers were in skilled occupations and served the general public. Male unskilled workers were listed as cooks, laborers, and miners. During this period of labor market segregation, skilled women were employed in positions to serve other women, such as tailoresses, mid-wives, and nurses. Female unskilled workers were listed as cooks and domestic workers. A final occupation category for women and men is included for illegibly written records and individuals without listed occupations.

Nativity and residence are also important characteristics in evaluating 19th and early 20th century net nutrition. International nativities are from Africa, Asian, Australia, Great Britain, Europe, Latin America, and Mexico. US nativities are from the Northeast, Middle Atlantic, Great Lakes, Plains, Southeast, Southwest, and Far West (Carlino and Sill, 2001). Women were

more likely to be incarcerated in urban locations. Incarceration was more likely among the young, and over 85 percent of urban and rural residents were younger than 40 years old (Table 2; Hirschi and Gottfredson, 1983; Gottfredson and Hirschi, 1990, pp. 128-144; Freeman 1993; Carson, 2009c; Patterson, 2005. p. 43). Skilled and workers without occupations were more likely to be urban, while unskilled workers were more likely to be rural. Race and ethnic status were similar across urban-rural locations but varied by nativity. For international nativity, British and European immigrants were more likely to be urban, while unskilled Mexicans were more likely to reside in rural US communities. US natives in the Far-West were more likely to live in rural areas, while individuals born in the Middle Atlantic were more likely to be urban. Urban-rural status was sensitive to residence, and individuals born in Illinois, Pennsylvania, and Tennessee were more likely to live in urban areas, while individuals born in Western Arizona and Montana were more likely to live in rural locations. Urban and rural residence did not vary greatly over time.

IV. Body Mass, Height, and Weight by Demographics, Socioeconomic Status, and Urban Residence

We now evaluate current and cumulative net nutrition by urban residence, gender, race, demographics, socioeconomic status, and time. To start, there are two ways to interpret net nutrition over time. Measured since birth, stature measures the variation in current net nutrition for the same cohort's cumulative net nutrition since birth. Body mass and weight are measured in the current period and illustrate how diverse cohort net nutrition varies at the time of measurement (Carson, 2019, p. 32).

Body Mass Index

$$BMI_i = \theta_0 + \theta_c Centimeters_i + \theta_f Female_i + \sum_{e=1}^{5} \theta_e Race_i + \sum_{a=1}^{15} \theta_a Age_i + \sum_{j=1}^{2} \theta_j Occupations_i + \sum_{n=1}^{13} \theta_n Nativity_i$$

$$+ \sum_{s=1}^{17} \theta_s \text{Re}sidence_i + \sum_{r=1}^{10} \theta_r Decade\,\text{Re}ceived_i + \sum_{m=1}^{13} \theta_m Urban_i + \varepsilon_i \qquad (1)$$

Height

$$Centimeter_i = \theta_0 + \theta_f Female_i + \sum_{e=1}^{5} \theta_e Race_i + \sum_{a=1}^{15} \theta_a Age_i + \sum_{j=1}^{2} \theta_j Occupations_i + \sum_{n=1}^{13} \theta_n Nativity_i$$

$$+ \sum_{s=1}^{17} \theta_s \text{Re}sidence_i + \sum_{r=1}^{10} \theta_r Decade\,\text{Re}ceived_i + \sum_{m=1}^{13} \theta_m Urban_i + \varepsilon_i \qquad (2)$$

Weight

$$Kio\log rams_i = \theta_0 + \theta_c Centimeters_i + \theta_f Female_i + \sum_{e=1}^{5} \theta_e Race_i + \sum_{a=1}^{15} \theta_a Age_i + \sum_{j=1}^{2} \theta_j Occupations_i + \sum_{n=1}^{13} \theta_n Nativity_i$$

$$+ \sum_{s=1}^{17} \theta_s \text{Re}sidence_i + \sum_{r=1}^{10} \theta_r Decade\,\text{Re}ceived_i + \sum_{m=1}^{13} \theta_m Urban_i + \varepsilon_i \qquad (3)$$

Table 3, Late 19th and Early 20th Century Urban and Rural BMIs by Characteristics

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*
	Total	US born males	US born females	Native Whites	Native Blacks	Youth	Adult
Intercept	32.78***	32.90***	44.41***	31.16***	36.59***	34.31***	31.99***
Height Centimeters	-.060***	-.059***	-.123***	-.049***	-.073***	-.069***	-.055***
Gender							
Male	Reference			Reference	Reference	Reference	Reference
Female	-.456***			.230*	-.892***	-.968***	-.101
Ethnicity							
White	Reference	Reference	Reference			Reference	Reference
Native American	.540****	.568***				.528**	.542***
Asian	-1.54***	-.345				-1.57***	-1.49***
Black	1.09***	1.15***	.578***		Reference	.953***	1.15***
Mixed-Race	.838***	.877***	.491***		-.292***	.673***	.925***
Mexican	.045	.019	.035			-.025	.065
Ages							
14	-3.42***	-3.38***	-3.50***	-2.63***	-3.77***	-3.34***	
15	-2.83***	-2.80***	-2.81***	-2.14***	-3.21***	-2.73***	
16	-2.10***	-2.13***	-1.52***	-1.73***	-2.41***	-1.97***	
17	-1.50***	-1.48***	-1.42***	-1.21***	-1.76***	-1.35***	
18	-1.12***	-1.12***	-.789***	-.894***	-1.35***	-.973***	
19	-.727***	-.706***	-.778***	-.569***	-.884***	-.567***	
20	-.438***	-.442***	-.336	-.317***	-.604***	-.270***	
21	-.299***	-.286***	-.465*	-.258***	-.355***	-.125***	
22	-.177***	-.158***	.428**	-.152***	-.207***	Reference	
23-29	Reference	Reference	Reference	Reference	Reference		Reference
30s	.258***	.234***	1.19***	.271***	.251***		.256***
40s	.509***	.492***	1.62***	.606***	.350***		.508***
50s	.591***	.592***	1.87***	.761***	.333***		.595***
60s	.478***	.413***	1.84**	.586***	.129		.487***
70s	.211	.235		.538**	-.159		.228
80s	-.313	-.925**		-.606	-1.31***		-.279
Occupation							

White Collar and Skilled	-.134***	-.092***		-.087***	-.177***	-.136***	-.127***
Unskilled	Reference	Reference	Reference	Reference	Reference	Reference	Reference
No Occupation	-.209***	-.182***	-.207	-.265***	-.179***	-.232***	-.188***
Nativity							
International							
Africa	.449					.673	.381
Australia	.031					.629*	-.058
Britain	.280***					.134	.285***
Canada	.266***					.136	.293***
Europe	.963***					.962***	.973***
Latin America	-.126					-.112	-.175
Mexico	-.040					.042	-.048
National							
Northeast	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle East	.156***	-.102*	-1.80	-.068	-.355*	.165*	.168***
Great Lakes	.270***	-.016	-1.56	-.013	-.252	.284***	.275***
Plains	.280***	-.025	-1.66	-.047	-.059	.367***	.257***
Southeast	.139**	-.178***	-2.12**	-.255***	-.142	.306***	.076
Southwest	.156***	-.170***	-2.00*	-.234***	-.173	.266***	.116*
Far West	.110*	-.186***	-1.97*	-.225***	-.223	.270**	.065
Residence							
Arizona	.027	.046	.812	.177***	-.374**	.103	.010
Colorado	.510***	.456***	.346	.513***	.364***	.385***	.546***
Idaho	.207**	.206**	1.09	.222*	.401	.033	.260**
Illinois	-.042	-.123**	.081	-.011	-.344***	-.151	-.020
Kentucky	-.426***	-.455***	.292	-.318***	-.560***	-.424***	-.451***
Missouri	-.734***	-.771***	.138	-.674***	-.827***	-.761***	-.725***
Montana	.707***	.668***	.233	.728***	.189	.653***	.724***
Mississippi	-.177***	-.198***	.440	-.053	-.309***	-.279***	-.127
Nebraska	-.551***	-.535***	-.085	-.497***	-.935***	-.622***	-.527***
New Mexico	.222***	.203***	-.537	.327***	-.054	.349***	.187***
Oregon	.799***	.870***	-1.92***	1.02***	.409	.764***	.804***
East, PA	-.320***	-.354***	.341	-.191***	-.700***	-.345***	-.317***
West, PA	.514***	.430***	1.65**	.561***	.427***	.581***	.492***
Philadelphia	-.336***	-.309***	-1.22**	-.278***	-.640***	-.478***	-.267***
Tennessee	.494***	.476***	.136	.504***	.454***	.569***	.410***

Texas	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Utah	.127***	.065		.149***		-.225***	.223***
Washington	-.136	-.312***		-.198*	-.398	-.117	-.136
Decade Received							
1840s	1.44***	1.53***		1.62***	1.20***	1.27***	1.50***
1850s	.571***	.589***		.579***	.704*	.407***	.663***
1860s	.697***	.690***	2.34**	.708***	.651***	.593***	.768***
1870s	.380***	.420***	.509**	.226***	.552***	.403***	.362***
1880s	.120***	.130***	.184	.097***	.121***	.085***	.140***
1890s	.126***	.151***	-.354**	.137***	.124***	.111***	.133***
1900s	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1910s	-.033***	-.056***	.508***	.032	-.136***	-.042	-.034
1920s	.123***	.096**	.301	.221***	-.125*	.138**	.119**
1930s	.133**	.133*	-.280	.235***	-.254	-.152	.184**
1940s	.069	.036		.051	-.157	.056	.073
Counties							
Rural	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Maricopa, AZ	-.010	-.005	.748	-.019	.108	-.257*	.068
Arapaho, CO	-.198***	-.136*	-.623	-.183**	-.109	-.323**	-.175**
Cook, IL	-.071	-.088	.699	-.032	-.082	-.091	-.061
Saint Louis, MO	.095**	.091*	.738	.191***	-.001	.162*	-.074
Douglas, NE	-.172***	-.208***	.185	-.059	-.026	.026	-.214***
Multanah, OH	-.525***	-.337***	4.97***	-.312**	.110	-.356**	-.569***
Philadelphia, PA	-.254***	-.398***	.071	-.314***	-.072	-.449***	-.192***
Alleghany, PA	-.234***	-.286***	-1.11	-.339***	-.133	-.378***	-.184**
Davidson, TN	-.082**	-.045	-.003	.037	-.143***	-.197***	.031
Hamilton, TN	-.505***	-.519***	.115	-.431***	-.549***	-.629***	-.402***
Shelby, TN	1.172***	-.180***	.063	-.156**	-.250***	-.317***	-.051
Knox, TN	-.138**	-.151**	.940*	.130	-.338***	-.226***	-.091
Jackson, MO	.112	.131*	-.431	.296**	-.017	.028	.160*
N	184,727	155,163	4,163	88,251	68,043	58,475	126,252
R^2	.1214	.1283	.1372	.0794	.1282	.1607	.0901

RMSE	2.39	2.34	3.64	2.40	2.34	2.13	2.49

Source: See Table 2.

Note: *** significant at .01; ** significant at .05; * significant at .10.

Table 4, Late 19th and Early 20th Century Urban and Rural Height in Centimeters by Characteristics

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	
	Total	US born males	US born females	Native Whites	Native Blacks	Youth	Adult
Intercept	171.90***	172.55***	163.32***	172.71***	170.63***	171.97***	171.75***
Gender							
Male	Reference			Reference	Reference	Reference	Reference
Female	-9.07***			-9.68***	-8.71***	-8.38***	-9.54***
Ethnicity							
White	Reference	Reference	Reference			Reference	Reference
Native American	-1.32***	-1.94***				-1.64***	-1.16***
Asian	-6.99***	-4.27***				-7.14***	-6.63***
Black	-2.17***	-2.27***	-.742**		Reference	-2.43***	-2.02***
Mixed-Race	-1.64***	-1.62***	-1.07***		.646***	-1.85***	-1.53***
Mexican	-4.18***	-5.23***	-5.25***			-4.58***	-3.96***
Ages							
14	-11.57***	-12.06***	-6.55***	-12.84***	-11.46***	-11.31***	
15	-7.91***	-8.31***	-.945	-8.58***	-7.86***	-7.68***	
16	-5.20***	-5.40***	-2.19***	-5.18***	-5.85***	-5.00***	
17	-3.19***	-3.31***	-.832*	-3.08***	-3.31***	-2.98***	
18	-2.04***	-2.07***	-.836*	-1.79***	-2.27***	-1.83***	
19	-1.25***	-1.32***	-.784	-1.17***	-1.41***	-1.05***	
20	-.553***	-.533***	-1.24**	-.451***	-.630***	-.379***	
21	-.240***	-.211***	-.131	-.221**	-.234**	-.059	
22	-.172***	-.156**	-.193	-.075	-.233**	Reference	
23-29	Reference	Reference	Reference	Reference	Reference		Reference
30s	-.070	.007	.532*	-.067	.190**		-.031
40s	-.696***	-.565***	.195	-.464****	-.584***		-.616***
50s	-1.39***	-1.36***	1.10	-1.21***	-1.36***		-1.28***
60s	-2.37***	-2.42***	-.190	-2.41***	-2.03***		-2.22***
70s	-3.18***	-3.44***		-3.41***	-2.21***		-2.99***
80s	-4.44***	-4.56***		-3.79***	-3.86***		-4.23***

Occupation							
White Collar and Skilled	-.195***	-.274***		-.187***	-.499***	-.305***	-.159***
Unskilled	Reference	Reference	Reference	Reference	Reference	Reference	Reference
No Occupation	-.053	-.076	-1.26***	.072	-.390***	-.442***	.146*
Nativity							
International							
Africa	-1.03					-3.58***	.267
Australia	.013					-.733	.146
Britain	-.626***					-.512	-.628***
Canada	.344*					.406	.355
Europe	-1.80***					-1.36***	-1.87***
Latin America	.232					-1.99**	.843**
Mexico	-1.20***					-.668*	-1.40***
National							
Northeast	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle East	.469***	-.355**	-1.72	-.366**	-.531	.581*	.455***
Great Lakes	1.45***	.718***	-1.04	.752***	.148	1.30***	1.52***
Plains	1.91***	1.20***	-1.27	1.30***	.170	2.02***	1.87***
Southeast	2.36***	1.68***	-1.03	1.73***	.925*	2.42***	2.35***
Southwest	2.49***	1.96***	-.368	1.73***	1.55***	2.61***	2.40***
Far West	1.76***	1.06***	-2.09	1.08***	.504	1.80***	1.72***
Residence							
Arizona	-2.28***	-1.86***	-1.13	-2.18***	.104	-2.75***	-2.07***
Colorado	-1.84***	-1.71***	-.432	-2.12***	-.271	-1.75***	-1.83***
Idaho	-.332	-.181	-.389	-.390	-.628	-.069	-.409
Illinois	-1.41***	-1.29***	-.371	-1.49***	-1.11***	-1.79***	-1.32***
Kentucky	-2.06***	-1.99***	-.410	-2.13***	-1.80***	-2.46***	-1.84***
Missouri	-1.50***	-1.49***	1.81***	-1.71***	-.910***	-1.60***	-1.44***
Montana	.281	1.27***	.453	1.03***	1.57***	1.07***	1.27***
Mississippi	1.21***	.311*	3.56**	.718*	.609***	.494*	.178
Nebraska	-.330***	-.337**	1.17	-.613***	.439	-.598**	-.392***
New Mexico	-.910***	-.792***	.334	-1.02***	.245	-.763***	-.940***
Oregon	-2.47***	-2.03***	-1.95**	-2.19***	-1.88**	-2.04***	-2.90***
East, PA	-3.17***	-2.81***	-1.31	-3.24***	-2.19***	-3.21***	-3.13***
West, PA	-2.14***	-1.87***	-.849	-2.15***	-1.09***	-2.41***	-2.02***

Philadelphia	-1.91***	-1.64***	-.314	-2.21***	-1.06***	-1.73***	-1.88***
Tennessee	-1.74***	-1.74***	2.55***	-1.84***	-1.18***	-1.49***	-1.86***
Texas	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Utah	-.668***	-.703***		-.912***		-1.11***	-.497***
Washington	-2.30***	-2.46***		-2.60***	-4.06**	2.65***	-2.16***
Birth Decade							
1770s	2.39	2.52		1.55	4.90***		1.98
1780s	-.371	-.393		-.739	-.942		-.635
1790s	2.88***	3.39**		4.37***	.866		2.56***
1800s	3.19***	3.49***		3.93***	1.05		2.93***
1810s	2.52***	2.93***	-4.45	3.08***	2.04***	6.94***	2.33***
1820s	1.51***	1.85***	-1.19	2.40***	.695**	4.40***	1.29***
1830s	.659***	.717***	-1.52	1.08***	-.006	1.23***	.561***
1840s	.473***	.492***	-.220	.656***	.277**	.571***	.440***
1850s	.309***	.344***	-.920**	.146*	.608***	.276**	.324***
1860s	.248	.278***	-.300	.172**	.418***	.280***	.224***
1870s	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1880s	-.294***	-.289***	-.424	-.326***	-.255***	-.482***	-.184***
1890s	-.035	.062	-.471	-.045	.138	-.215**	.142*
1900s	.749***	.824***	1.31*	.802***	.870***	.319**	1.29***
1910s	2.43***	2.55***	2.16	2.52***	2.73***	2.08***	2.78***
1920s	4.08***	4.28***		4.19***	4.24*	3.87***	5.88**
Counties							
Rural	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Maricopa, AZ	-.318	-.227	-4.94	-.426	.854	.469	.586**
Arapaho, CO	.074	-.177	2.65***	.049	-.478	.263	.019
Cook, IL	-.414***	-.484***	-.641	-.726***	.226	-.093	-.468***
Saint Louis, MO	-1.10***	-1.08***	-3.41***	-.784***	-1.70***	-1.25***	-1.08***
Douglas, NE	-.533***	-.377**	-.789	-.479***	-.507	-.150	-.629***
Multanah, OH	-.916***	-.854**	7.00***	-.964***	1.17	-1.26**	-.784**
Philadelphia, PA	-.568***	.761***	-2.70**	-.591***	-.974***	-1.01***	-.503***
Alleghany, PA	-1.06***	-1.14***	.918	-1.15***	-1.12***	-1.19***	-1.01***

Davidson, TN	-1.06***	-1.08***	-2.11***	-1.01***	-1.03***	-1.19***	-.956***
Hamilton, TN	-.462***	-.485**	-1.47	-1.40***	-.216	-.466**	-.468**
Shelby, TN	-1.43***	-1.51***	-1.50***	-1.88***	-1.33***	-1.65***	-1.27***
Knox, TN	-.166	-.182	.884	-.029	-.374*	-.587***	.134
Jackson, MO	-.903***	-.914***	-.032	-1.01***	-.718***	-.860***	-.944***
N	184,727	155,163	4,163	88,251	68,043	58,475	126,252
R^2	.1561	.1088	.0681	.1188	.1555	.1990	.1282
RMSE	6.50	6.47	6.76	6.33	6.67	6.47	6.51

Source: See Table 2.

Note: *** significant at .01; ** significant at .05; * significant at .10.

Table 5, Late 19th and Early 20th Century Urban and Rural Weight in Kilograms by Characteristics

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*	*Model 7*
	Total	US born males	US born females	Native Whites	Native Blacks	Youth	Adult
Intercept	-40.04***	-39.69***	-7.68*	-42.60***	-31.62***	-32.81***	-43.62***
Height Centimeters	.620***	.623***	.446***	.638***	.599***	.576***	.641***
Gender							
Male				Reference	Reference	Reference	Reference
Female	-1.22***						
Ethnicity				.638**	-2.32***	-2.60***	-.292
White	Reference	Reference	Reference			Reference	Reference
Native American	1.57***	1.68***				1.43**	1.62***
Asian	-4.08***	-.790***				-4.17***	-3.94***
Black	3.20***	3.37***	1.48***		Reference	2.78***	3.35***
Mixed-Race	2.47***	2.59***	1.26***		-.864***	1.97***	2.73***
Mexican	.210*	.156	-.159			.024	.250*
Ages							
14	-8.70***	-8.62***	-8.48***	-6.40***	-9.59***	-8.64***	
15	-7.56***	-7.52***	-7.11***	-5.83***	-8.58***	-7.39***	
16	-5.78***	-5.90***	-3.90***	-4.77***	-6.65***	-5.48***	
17	-4.22***	-4.21***	-3.62***	-3.43***	-4.95***	-3.84***	
18	-3.21***	-3.23***	-2.10***	-2.58***	-3.87***	-2.79***	
19	-2.11***	-2.06***	-2.13***	-1.67***	-2.57***	-1.65***	
20	-1.28***	-1.30***	-.934	-.933***	-1.77***	-.783***	
21	-.865***	-.832***	-1.34**	-.750***	-1.03***	-.347***	
22	-.528***	-.477***	-1.15**	-.462***	-.612***	Reference	
23-29	Reference	Reference	Reference	Reference	Reference		Reference
30s	.752***	.696***	3.03***	.806***	.712***		.746***
40s	1.48***	1.46***	4.20***	1.80***	1.02***		1.49***
50s	1.70***	1.72***	4.74***	2.22***	.929***		1.72***
60s	1.38***	1.21***	4.72**	1.73***	.293		1.42***
70s	.634	.690		1.54**	-.443		.698
80s	-.775	-2.63**		-1.76	-3.67***		-.658
Occupation							

White Collar and Skilled	-.377***	-.263***		-.247***	-.497***	-.374***	-.362***
Unskilled	Reference	Reference	Reference	Reference	Reference	Reference	Reference
No Occupation	-.577***	-.516***	-.548	-.741***	-.495***	-.644***	-.528***
Nativity							
International							
Africa	1.22					1.98***	.978
Australia	.164					1.81*	-.084
Britain	.794***					.395	.815***
Canada	.749***					.421	.816***
Europe	2.73***					2.75***	2.77***
Latin America	-.362					-.184	-.545
Mexico	-.118					.101	-.125
National							
Northeast	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle East	.437***	-.270	-5.10*	-.171	-1.01*	.479*	.460**
Great Lakes	.762***	-.017	-4.48	.008	-.709	.781***	.774***
Plains	.769***	-.061	-4.80	-.103	-.163	1.02***	.696***
Southeast	.359**	-.515***	-5.92**	-.714***	-.400	.840***	.169
Southwest	.390**	-.496***	-5.67*	-.670***	-.517	.727**	.285
Far West	.263	-.545***	-5.64*	-.642***	-.672	.743**	.126
Residence							
Arizona	.154	.185	1.86	.552***	-1.03**	.356	.099
Colorado	1.52***	1.38***	1.02	1.54***	1.03**	1.22***	1.62***
Idaho	.640**	.633**	3.29	.700**	1.04	.103	.803**
Illinois	-.095	-.328**	.243	-.011	-.962***	-.395	-.037
Kentucky	-1.20***	-1.29***	.823	-.907***	-1.58***	-1.18***	-1.29***
Missouri	-2.09***	-2.20***	.328	-1.93***	-2.35***	-2.15***	-2.07
Montana	2.15***	2.04***	.638	2.25***	.533	-.855***	2.19***
Mississippi	-.571***	-.628***	1.10	-.200	-.981***	1.98***	-.410*
Nebraska	-1.58***	-1.54***	-.302	-1.43***	-2.67***	-1.79***	-1.50***
New Mexico	.631***	.570***	-1.15	.938***	-.201	1.04***	.518***
Oregon	2.40***	2.62***	-4.79***	3.04***	1.08	2.29***	2.41***
East, PA	-.825***	-.940***	.951	-.455***	-1.93***	-.887***	-.816***
West, PA	1.54***	1.31***	4.19**	1.68***	1.25***	1.73***	1.47***
Philadelphia	-.847***	-.835***	-2.94**	-.684***	-1.69***	-1.22***	-.663***
Tennessee	1.41***	1.37***	.401	1.46***	1.29***	1.62***	1.19***

Texas	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Utah	.445***	.267*		.517***		-.559**	.707***
Washington	-.311	-.814**		-.516	-.734	-.215	-.332
Decade Received							
1840s	4.26***	4.58***		4.88***	3.59***	3.74***	4.45***
1850s	1.68***	1.75***		1.75***	1.92*	1.20***	1.94***
1860s	2.02***	2.01***	5.74**	2.11***	1.83***	1.70***	2.24***
1870s	1.08***	1.21***	1.16*	.646***	1.58***	1.19***	1.01***
1880s	.352***	.381***	.485	.293***	.343***	.258***	.407***
1890s	.361***	.435***	-.954**	.396***	.362***	.321***	.382***
1900s	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1910s	-.109**	-.170***	1.26***	.088	.422***	-.134*	-.109*
1920s	.323***	.256**	.725	.623***	-.392*	.397**	.303**
1930s	.341*	.344*	-.838	.664***	-.822	-.530	.485**
1940s	.087	-.010		.076	-.574	-.025	.093
Counties							
Rural	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Maricopa, AZ	-.025	.013	1.74	-.053	.391	-.710*	.202
Arapaho, CO	-.551***	-.381	-1.71	-.515**	-.261	-1.01***	-.459*
Cook, IL	-.178	-.232	1.88*	-.073	-.232	-.214	-.149
Saint Louis, MO	.283**	.284*	1.52	.570***	-.008	.410*	.246
Douglas, NE	-.497***	-.603***	.621	-.185	-.088	-.064	-.616***
Multanah, OH	-1.48***	-.995***	13.49***	-.941***	.461	-1.01*	-1.60***
Philadelphia, PA	-.765***	-1.12***	.034	-.937***	-.268	-1.33***	-.592***
Alleghany, PA	-.702***	-.816***	-2.72	-.969***	-.377	-1.11***	-.559***
Davidson, TN	-.169***	-.080	.154	.125	-.313**	-.494***	.133
Hamilton, TN	-1.45***	-1.49***	.120	-1.25***	-1.57***	-1.81***	-1.15***
Shelby, TN	-.463***	-.483***	.174	-.427*	-.658***	-.872***	-.138
Knox, TN	-.368**	-.398**	.241	.385	-.917***	-.609***	-.248
Jackson, MO	.331	.388*	-1.35-1.35	.741***	-.020	.113	.453
N	184,727	155,163	4,163	88,251	68,043	58,475	126,252
R^2	.3567	.3543	.1947	.3194	.4043	.4298	.3071

RMSE	6.88	6.80	6.40	7.04	6.07	6.04	7.22

Source: See Table 2.

Note: *** significant at .01; ** significant at .05; * significant at .10.

Height in centimeters are included in BMI and weight models to account for the inverse relationship between height and BMI and the positive relationship between height and weight (Carson, 2009a; Carson, 2012; Komlos and Carson, 2017). A female gender dummy variable is included to account for sexual dimorphism and net nutrition (Bogin, Scheffler, and Hermanussen, 2016, p. 6; Meisel-Roca et al 2023). Race dummy variables are included for black, mixed-race, Mexican, Asian, and Native American racial groups (Steckel, 1979; Carson, 2008; Carson, 2009). Yearly age variables are included for individuals in their teens and early 20s. Adult decade variables are included for older ages to account for the relationship between age and net nutrition (Twarog, 1997, pp. 304-305; Bogin, Staffler, and Hermanussen, 2016, p. 6). Occupation dummy variables measure the relationship between net nutrition and socioeconomic status (Steckel and Haurin, 1994, pp. 122-125). Nativity dummy variables measure the relationship between net nutrition and early life conditions. Residence variables account for the relationship between net nutrition and current environmental conditions. Birth period is used to measure statures over time, while observation periods are used to measure BMI and weight for the period of measurement (Carson, 2019, p. 32). Discrete urban county variables are included to measure net nutrition variation and urban conditions (Komlos, 1987).

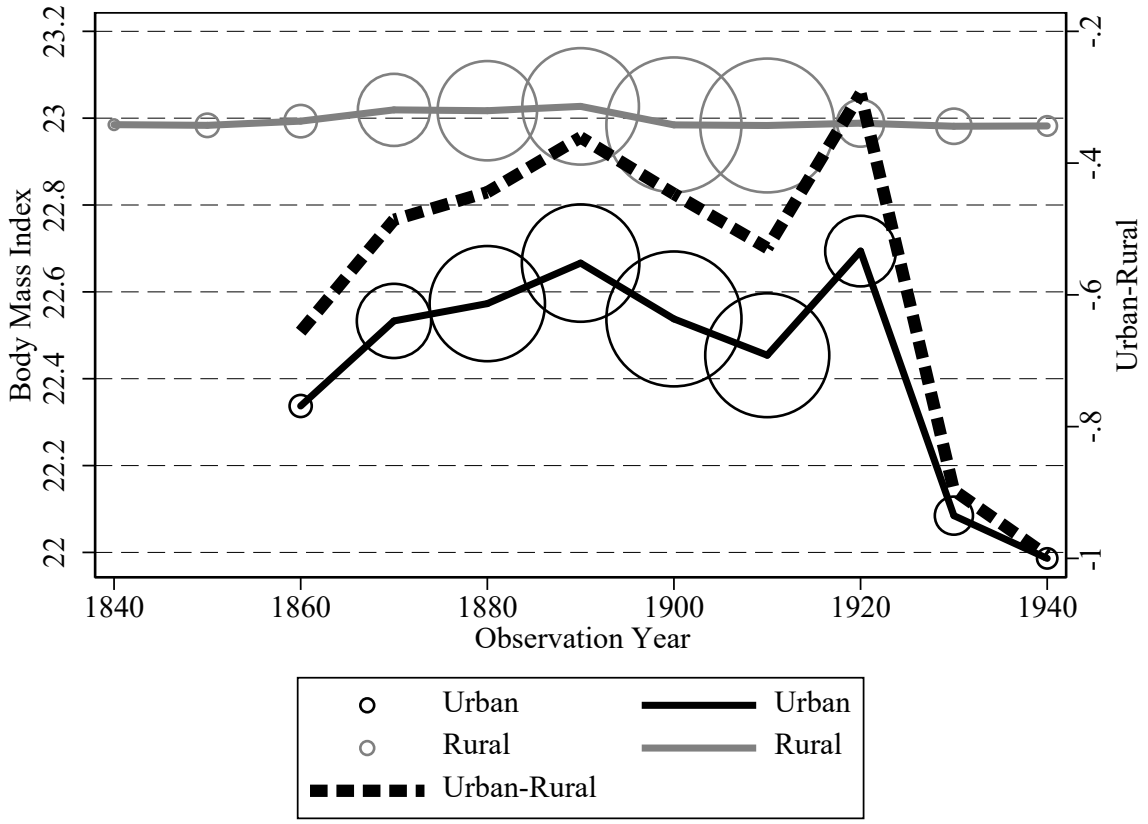

Figure 3, Late 19th and Early 20th Century Urban and Rural BMIs over Time

Source: Stature regression coefficients from Table 3, Models 1 and 2, are weighted by sample size in Table 2.

Note: Circle size represents sample proportion.

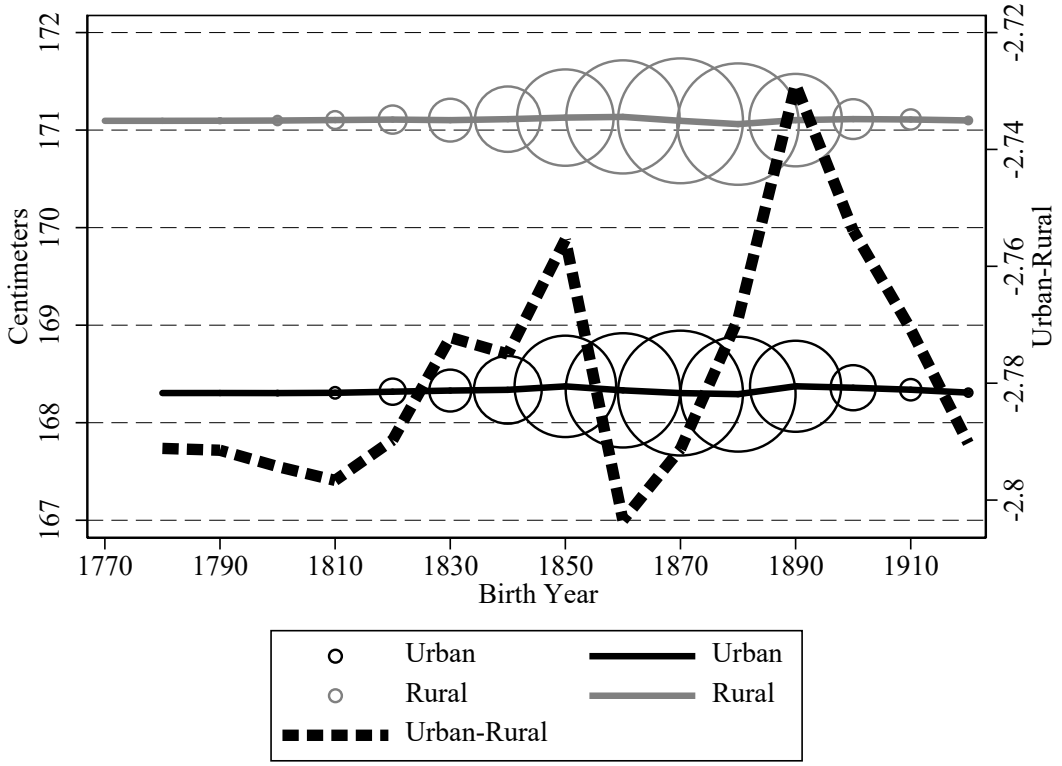

Figure 4, Late 19th and Early 20th Century Urban and Rural Heights over Time

Source: Stature regression coefficients from Table 4, Models 4 and 5, are weighted by sample size in Table 2.

Note: Circle size represents sample proportion.

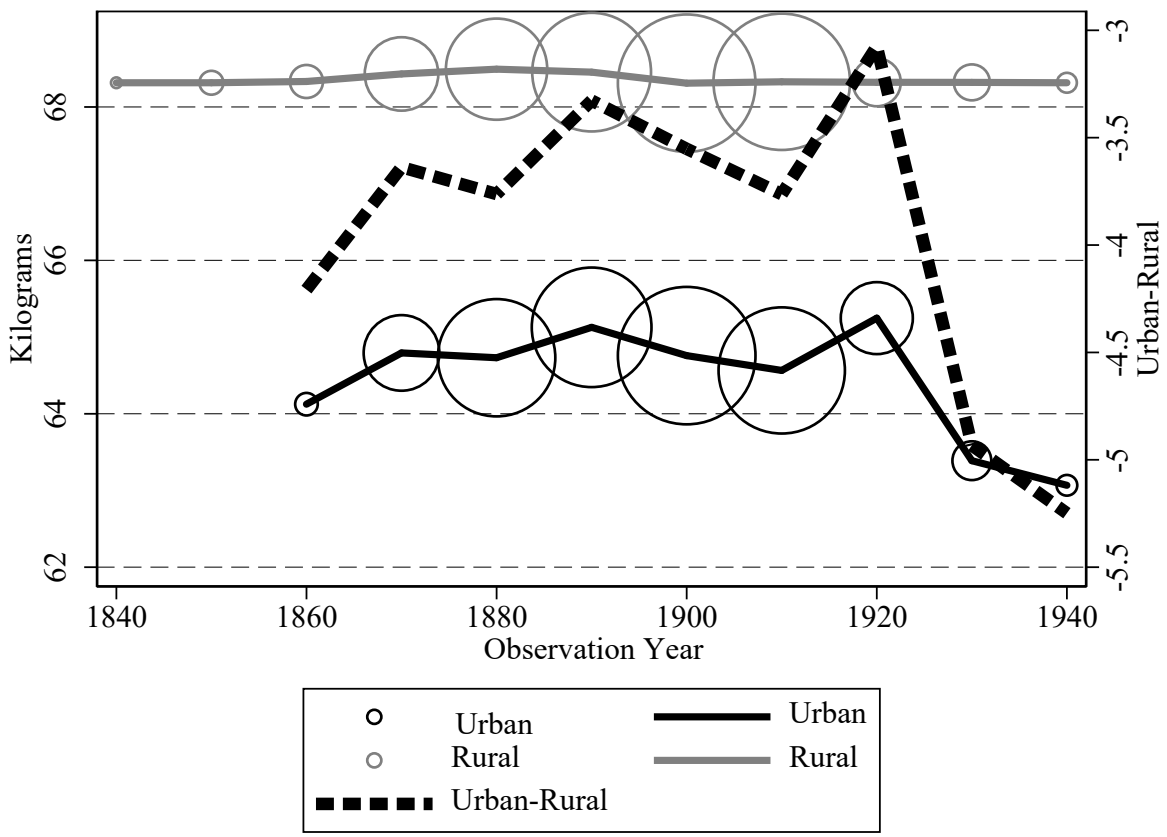

Figure 5, Late 19th and Early 20th Century Urban and Rural BMIs over Time

Source: Stature regression coefficients from Table 6, Models 1 and 2, are weighted by sample size in Table 2.

Note: Circle size represents sample proportion.

A persistent concern in net nutrition studies is unobserved sample selection bias, which is addressed in this study with bubble proportions by weighting time coefficients by sample size and is illustrated in Figures 3 and 4 (Zimran, 2019; Neubzer, 2019, p. 235, Figure 3, Figure 4, and Figure 5).

Three paths of inquiry are considered when evaluating net nutrition and urbanization during US economic development. First, health effects associated with net nutrition and urbanization have long been associated with stature and health studies (Zehetmayer, 2011; Davidson, et al 2002, pp. 238-241; Carson, 2008b, pp. 238-241; Berecki et al. 2019, p. 187; Meinzer, 2019, p. 232), and individuals in the 19th and early 20th century urban US had lower BMIs, shorter statures, and lower weight than rural residents, demonstrating a net nutritional penalty and willingness to accept poorer net nutrition in exchange for urban economic opportunity (Table 3, Table 4, and Table 5; Heirmeyer, 2010; Zehetmeyer, 2013). Net nutrition by urban residence reflects material conditions and technological change associated with calories required for work and to withstand the disease environment (Gordon, 2015, pp. 83-84). Before 1860, most of the US was rural and used rudimentary agricultural techniques. In 1834, Cyrus McCormick patented and began manufacturing his agricultural reaper (Cochrane, 1979, pp. 67-68 and 190-195; Olmstead and Rhode, 2008, pp. 4 and 63). Shortly after in 1837, John Deere—an Illinois blacksmith—developed the first commercially successful steel plow. Tractors and various plant hybrids were developed later, which increased agricultural productivity throughout the US economy, and urbanization decreased access to food and increased its acquisition costs. Stature is also related to calcium and milk consumption, and urban areas separated milk consumption from production (Wiley, 2005). The quality of US dairy deteriorated with the separation of food production from consumption, where milk was watered and whitened when milk was stored in cans, which hastened spoilage (Carson, 2008a, p. 349; Gordon, 2015, pp. 81-82). In 1840, most food was produced on rural farms that primarily produced butter and cheese for household consumption (Hilliard, 1972). By 1900, US dairy production was a highly specialized and efficient commercial enterprise that separated dairy consumption from

production (Atack and Bateman, 1987, pp. 201-224; Carson, 2008b, pp. 149-150; Gordon, 2015, pp. 81-82).

Urban net nutrition was also adversely affect by disease, which was more common in urban areas (Twarog, 1997, pp. 312-316; Haines, Craig, and Weiss, 2003, pp. 395-409; Floud et al. 2011, pp. 231, 321, 334-335; Zehetmeyer, 2011; Zehetmeyer, 2013; Carson, 2020; Carson, 2022). Close proximity in densely populated urban areas facilitated the spread of communicable diseases that required calories otherwise devoted to stature growth and net nutrition (Barry, 2005, pp. 197-209). Urban statures may also be affected by pollution, where urban individuals face higher disease mortalities, putting greater claims on urban diets (Pope and Miner, 1988; Alfoni, 2022, p. 32; Baldwin, 1999, pp. 128-129). It has long been known that stature is inversely related to lead poisoning (Schwartz, Angle, and Pitcher, 1986, pp. 281-282), and lead was common in early economic development, which increased pollution associated with disease mortality (Clay, Lewis, and Severnini, 2018; Afani, 2022, pp. 61-62).

Although the causal link is less clear, burning coal generates high carbon dioxide, sulfur dioxide, and nitrogen oxide, which are related to increased morbidity and higher mortality rates. Urban coal use also increases soot, which may reduce calcium absorption that is essential in stature growth (Wiley, 2005; Gordon, 2015, pp. 220 and 225; Carson 2011a; Carson, 2011b, Carson, 2015). Increased atmospheric pollutants reduces the amount of solar radiation available to synthesize cholesterol within the epidermis to produce vitamin-D, which is essential in calcium absorption (Bailey et al 2018; Carson 2008; Carson, 2009, Carson, 2010). Urban coal and pollution, subsequently, put stress on 19th century net nutrition through diseases associated with lower urban net nutrition. Consequently, urban consumption separated rural agriculture

from production decreased rural net nutrition, and there was a net nutrition penalty in exchange for greater urban economic opportunity.

Second, results are mixed, however, regarding the magnitude of the urban gender-penalty (Tables 3-6). For example, female urban body mass was not affected by urban status, whereas urban male body mass was lower (Table 3, Models 4, 5, and 6). Nineteenth and early 20th century US labor markets were partitioned by gender, and urban males were more likely to work outside the home in physically demanding occupations, where they were more exposed to infectious diseases than urban females and rural males (Carson, 2020; Carson, 2022). In health studies, male stature appears more subject to adverse environmental conditions than females. Sexual dimorphism is the biological pattern between genders, where gender-based sexual dimorphism existed because how men and women respond to environmental and socioeconomic conditions (Costa-Font and Gil, 2008; Bogin et al 2023, p. 125). During adverse environmental conditions, adult male heights may be more negatively affected than female heights (Bogin et al 2016).

Part of gender-based net nutrition differences may also be due to women being involved in domestic activity (Lui et al 2021), and United Kingdom stature studies indicate similar gender patterns. Nineteenth century British and Irish net nutrition by gender reflects urban conditions, and the quality of Irish peasant diets in English industrializing communities. Rural Irish men were .4 centimeters taller than English rural men, indicating that Irish men came to maturity under better cumulative net nutrition conditions than English men (Nicholas and Steckel, 1997, 111; Bogin, 2001, p. 255). Northern rural English females diets averaged around 2,823 calories per day, while southern female diets average around 2,109 calories per day, and urban English diets had lower quality with less variety. Urbanization also restricted urban diets (Nicholas and

Steckel, 1997, p. 116; Bogin, 2001, p. 255). English urban diets individuals varied by socioeconomic status, and English female urban diets were of lower quality because they were less physically active within the household. Alternatively, urban English males received greater calorie allocations because they were physically active and worked outside the home (Oren, 1973, pp. 107-111). Subsequently, because they were more exposed to urban labor markets, urban males experienced more of the net nutrition penalty than females.

Third, urban material and nutritional conditions varied by race, and individuals with darker complexions had higher BMIs, shorter statures, and greater weight after correcting for height (Table 3 and Figures 3, 4, and 5). Steckel (1979) was the first to show that individuals with fairer complexions were consistently taller than individuals with darker complexions. Higher urban population's mixed-race concentrations may have been associated with better net nutritional conditions because of progressive urban institutions that shielded urban blacks from rural prejudice, associated with higher urban black BMIs and heavier weights (Higgs, 1977, pp. 35-37). Fogel and Engerman (1974, p. 132) and Johnson (1941, pp. 256-257) show that mixed-race African and European-Americans with fairer complexions were more common in 19th century urban areas.

Bodenhorn (1999) and Bodenhorn (2002, p. 23, 30, and 43) attribute taller mixed-race statures to antebellum social preferences that disproportionately favored mixed race individuals. If taller statures accrued to fairer complexioned individuals because of social preferences, individuals with fairer complexions would have taller statures, higher BMIs, and heavier weights (Tables 3, 4, and 5; Higgs, 1977, p. 31, 34, and 37 ; Carson, 2022). In fact, the opposite is true, and individuals with fairer complexions had taller statures and lower body mass, and lighter weights (Carson, 2015a; Carson, 2015b). If urban social and economic conditions put pressure

on urban net nutrition that foreclosed lower socioeconomic blacks from economic opportunity, urban black net nutrition may have been worse than urban white net nutrition. Subsequently, urban blacks faced poorer cumulative net nutrition but had higher BMIs and heavier weights.

Other patterns are consistent with expectations. Male and female statures varied differently by age associated with sexual dimorphism that does not vary over time (Meisel-Roca, 2023; pp. 125, 127-128; Camara,2015; Nikitovic and Bogin, 2014; Stinson, 1985). As males grow, they are taller and mature more slowly than females; however, males are exposed to environmental influences that change their stature phenotype. Ortona et al (2019) indicate males are taller than females but may have a greater penalty during adverse events because women have stronger adaptive immune responses compared to males, which puts less stress on female net nutrition devoted to stature growth. Genetic factors also contribute to sexual dimorphism, and females have better survival rates than males because their X chromosome responds more aggressively to various immune changes (Pickerington, et al. 2015).

V. Decomposing the Urban-Rural BMI, Height, and Weight Difference

To more fully account for late 19th and early 20th century urban-rural net nutrition by race and genders, net nutrition is decomposed into structural returns to characteristics and compositional returns to average characteristics. Let γ_h and γ_l be high and low net nutrition variation by characteristics. X_h and X_l are average characteristic matrices. θ_{h0} and θ_{l0} are high and low autonomous net nutritional sensitivities. θ_{h1} and θ_{h1} are high and low net nutritional sensitivities associated with characteristics.

$$\gamma_h - \gamma_l = \left(\theta_{0h} - \theta_{0l}\right) + \left(\theta_{1h} - \theta_{1l}\right)\bar{X}_l + \left(\bar{X}_h - \bar{X}_l\right)\theta_h \qquad (4)$$

$$\gamma_h - \gamma_l = \left(\theta_{0h} - \theta_{0l}\right) + \left(\theta_{1h} - \theta_{1l}\right)\bar{X}_h + \left(\bar{X}_h - \bar{X}_l\right)\theta_l \quad (5)$$

Equation 4 is low average characteristics at high returns to characteristics. Equation 5 is high average characteristics at low returns to characteristics. Equations 4 and 5's first right-hand side element, $\left(\theta_{0h} - \theta_{0l}\right)$, is the autonomous characteristic differences due to non-identifiable characteristics, such as wealth, disease, and diet. The second right hand side element, $\left(\theta_{1h} - \theta_{1l}\right)\bar{X}_l$, are structural returns difference due to characteristics. The third right-hand side element, $\left(\bar{X}_h - \bar{X}_l\right)\theta_h$, is the composition difference, and a large composition difference indicates that dependent variable differences are due to sample differences associated with compositions rather than returns to characteristics.

Table 6, Late 19th and Early 20th Century Urban and Rural BMIs, Height, and Weight Decompositions by Gender

BMI	$(\theta_m - \theta_f)X_m$	$(X_m - X_f)\theta_f$	$(\theta_m - \theta_f)X_f$	$(X_m - X_f)\theta_m$
Level				
Sum	.656	-1.15	.248	-.745
Total		-.498		-.498
Proportion				
Intercept	23.13		23.13	
Centimeters	-21.99	2.44	-20.72	1.17
Complexion	-.422	.246	-.652	.476
Age	.809	-.446	.724	-.361
Occupations	.045	.056	-.001	.103
Nativity	-3.55	-.074	-3.61	-.013
Residence	.269	-.031	.152	.087
Received	.179	-.047	.136	-.004
Urban	.211	.171	.342	.040
County				
Sum	-1.32	2.32	-.498	1.49
Total		1		1
Height				
Level				
Sum	9.71	-.061	8.78	.866
Total		9.65		9.65
Proportion				
Intercept	.957		.957	
Race	-.050	.016	-.079	.044
Age	-.054	.019	-.070	.035
Occupations	.012	-.018	.003	-.009
Nativity	.235	-.005	.241	-.011
Residence	-.171	-.015	-.196	.010
Birth Period	.054	-.005	.040	.008
Urban	.024	.001	.013	.012
Counties				
Sum	1.01	-.006	.910	.090
Total		1		1
Weight (kg)				
Level				
Sum	2.23	4.61	1.18	5.66
Total		6.85		6.85
Proportion				
Intercept	-4.68		-4.68	
Centimeters	4.42	.644	4.16	.899

Complexions	.104	-.046	.159	-.102
Age	-.129	.085	-.117	.074
Occupations	-.010	-.011	1.23^{-4}	-.021
Nativity	.729	.015	.741	.003
Residence	-.052	.005	-.031	-.017
Year	-.026	.009	-.018	.001
Observed Urban Counties	-.035	-.026	-.051	-.009
Sum	.326	.674	.173	.827
Total		1		1

Source: See Tables 2, 4, 5, and 6. Male-female BMI coefficients are from Table 3, Models 2 and 3. Male-female stature coefficients are from Table 4, Models 2 and 3. Male-female weight coefficients are from Table 5, Models 2 and 3.

Table 6 presents gender urban-rural decompositions by body mass, height, and weight. Independent of characteristics, women had greater body mass, while men had taller statures with heavier weights. Partitioning net nutrition by characteristics, female BMI returns to characteristics nearly offsets the male BMI advantage. BMI returns to individual characteristics are larger than returns to average characteristics. Other characteristics are smaller but had meaningful effects, and female BMI returns by nativity were greater than males. Alternatively, gender stature decompositions illustrate that males were taller than females, which was due to the autonomous intercepts and sexual dimorphism. The male-female urban stature difference is small. In sum, differences in average characteristics affected body mass because females have greater returns to body mass with height, but males were genetically taller.

Male-female weight differences are mostly associated with heavier female compared to male weights independent of characteristics. However, male weight returns to stature offsets the female weight advantage. Nativity also had a large male gender advantage, and the effects of higher average male weight favored men. The male-female weight difference is small, and urban

females had greater returns than urban males from returns to characteristics and average characteristics (Meisel-Roca, et al. 2023, pp. 125-126 and 131-138). Subsequently, a gender decomposition illustrates that most male-female net nutrition differences by gender favored men associated with sexual dimorphism.

Table 7, Late 19th and Early 20th Century Black and White BMIs, Height, and Weight Urban-Rural Decompositions by Race

BMI	$(\beta_b - \beta_w)X_w$	$(X_b - X_w)\beta_b$	$(\beta_b - \beta_w)X_b$	$(X_b - X_w)\beta_w$
Level				
Sum	.785	.119	1.05	-.148
Total		.904		.904
Proportion				
Intercept	6.01		6.01	
Centimeters	-4.56	.155	-4.51	.104
Gender	-.018	-.027	-.052	.007
Age	-.141	-.268	-.189	-.212
Occupations	-.086	.026	.010	-.013
Nativity	-.086	.047	.060	-.100
Residence	-.263	.173	-.136	.046
Received	-.055	.039	-.010	-.006
Urban Counties	.009	-.020	-.021	.011
Sum	.868	.132	1.16	-.134
Total		1		1
Height	$(\beta_w - \beta_b)X_b$	$(X_w - X_b)\beta_w$	$(\beta_w - \beta_b)X_w$	$(X_w - X_b)\beta_b$
Level				
Sum	2.05	.130	2.21	-.030
Total		2.18		2.18
Proportion				
Intercept	.953		.953	
Gender	-.007	.109	-.019	.121
Age	.002	.173	.018	.157
Occupations	.080	-.038	.070	-.027
Nativity	.268	-.271	.284	-.287
Residence	-.325	.033	-.228	-.064
Received	-.024	.017	-.040	.032
Urban Counties	-.007	.037	-.025	.054

Sum	.940	.060	1.01	-.014
Total		1		1
	$(\beta_b - \beta_w)X_b$	$(X_b - X_w)\beta_w$	$(\beta_b - \beta_w)X_w$	$(X_b - X_w)\beta_b$
Level				
Sum	2.92	-1.22	2.92	-1.22
Total		1.71		1.71
Proportion				
Intercept	6.44		6.44	
Centimeters	-3.92	-.672	-3.88	-.715
Gender	-.025	-.037	-.072	.010
Age	-.222	-.384	-.289	-.318
Occupations	-.043	.040	.015	-.018
Nativity	-.143	.069	.082	-.156
Residence	-.413	.256	-.211	.054
Received	.031	.040	.080	-.009
Urban	.016	-.027	-.029	.017
Counties				
Sum	1.71	-.714	2.14	-1.14
Total		1		1

Source: Black-white BMI coefficients are from Table 3, Models 2 and 3. Black-white stature coefficients are from Table 4, Models 2 and 3. Black-white weight coefficients are from Table 5, Models 2 and 3.

Net nutrition returns varied by complexion and race, and individuals of African ancestry with darker complexions consistently had higher BMIs and heavier weights than individuals of European ancestry (Table 7). However, because of fairer complexions, greater vitamin D production, and socioeconomic effects, individuals of Europeans ancestry are consistently taller than individuals of African ancestry. While darker complexioned individuals have higher BMIs, much of the advantage is offset by greater BMI returns associated with stature. Urban BMI, stature, and weight race differences across complexions were small (Carson, 2023). Consequently, only a small share of net nutrition by gender and race were associated with urban status, and most of the body mass, stature, and weight complexion differences are associated with genetically determined sexual dimorphism.

VI. Conclusion

When traditional income and wealth measures are scarce or unreliable, body mass, stature, and weight are standard biological compliments to material welfare measures. Moreover, traditional income and wealth exclude non-pecuniary measures, such as urban-rural nutrition differences, medical intervention, and pollution, and these small variations have large effects by gender and race. Results are mixed by gender and women's body mass was unaffected by urbanization, while urban males had lower BMIs, shorter statures, and lower weights. Urban material conditions varied by race, and both urban blacks and whites had lower BMIs, shorter statures, and lower weight. Urbanization during economic development imposes costs on health, net nutrition and diets, and urban women and men accepted diminished net nutrition and poorer health in exchange for urban economic opportunity. Subsequently, 19th and early 20th century US urbanization imposed a compensating urban net nutritional penalty experienced by gender and race.

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