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Abstract

Alternative measures for material conditions are frequently used to evaluate economic welfare during development. The basal metabolic rate and calories are two alternative net nutrition measures that vary by demographics, nativity, residence, and socioeconomic status. During the 19th and early 20th centuries, males required about 20 percent more calories per day than females, and physically active laborers required more calories per day than sedentary white-collar and skilled workers. Individuals from rural Montana and the South required more calories per day than individuals from elsewhere within the US.

JEL-Codes: Q100, Q190, N110, N510.

Keywords: nineteenth and 20th century US gender relations, net nutrition, physical activity, nineteenth and 20th century US race relations.

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I. Introduction

Resource allocation during economic development accrues across time, demographics, socioeconomic status, and geographic regions. Income and wealth are two common measures that reflect resource allocation, economic growth, and inequality that are shared household resources. Furthermore, income and wealth collectively accrue to households, which distorts how resources accrue individually within the household and within an economy. Nonetheless, because they fail to measure pollution and the negative effects of economic development, income and wealth are incomplete measures for material conditions (Nordhaus, 2003, p. 20). When income and wealth are not available or reliable, there are alternative welfare measures that reflect material conditions, such as height, body mass, and net nutrition (Steckel 1983; Floud et al. 2011, p. 46), and physical measures for height and weight augment income and wealth studies. Calorie distributions by gender and race shed light on resource production and allocation in the paid-labor force, life expectancy, and the physical environment (Floud et al, 2011, pp. 108-112; Craig, Haines, and Weiss, 2003). However, because individual dietary records were generally not maintained, historical calorie estimates are elusive (Floud et al, 2011, p. 46). This study, therefore, uses physical measures to estimate calorie requirements to maintain worker's weight, height, and physical activity by gender and race across the late 19th and early 20th century calorie distribution and are related to how resources were allocated within the household and within the US economy.

Nineteenth and early 20th century material and nutrition allocation was influenced by economic conditions, agricultural productivity, and social custom. During economic development, the paid-labor force requires greater physical activity, strength, and net nutrition that disproportionately accrues to men (Bleakley and Costa, 2013, pp. 5-10), and because women did not have income and wealth independent from husbands and fathers, alternative net nutrition measures reflect access to resources that accrue to individuals that are masked by collectively held household income and wealth (Jennings, 1992; Levy, 2021, pp. 42-43, and 56; Carson, 2022). In the 19th century US, conditions facing women and men varied with economic and political events, and various innovations developed that changed gender roles in labor markets (Lunardini, 1997, pp. 95-96, 143-145; Floud et al. 2011, pp. 35, 37, and 160; Gordon, 2015, pp. 96-97). During US industrialization, women found labor market niches, and wherever 18th and 19th century manufacturing spread, women's wages increased, and occupational opportunities improved (Goldin and Sokoloff, 1982; Brands, 2010, p. 106; Besson, 2015, p. 224; Levy, 2021, pp. 167-168). Innovations also changed physical requirements that altered women's roles, relative productivity, and calorie requirements (Fogel and Costa, 1997, 49-66; Fogel, 2000; Gordon, 2015, pp. 6, 250-254).

Conditions within the household were also affected by political and legal events. By 1872, the Missouri suffrage leader—Virginia Miner—tried to vote in a Missouri state election but was refused because of her gender (Lunardini, 1997, pp. 102-104). She took her case to the Missouri Supreme Court, where she was denied. In 1874, her case was heard before the United States Supreme Court in Minor vs. Happersett and was again denied. Various suffrage movements followed (Jennings, 1992, pp. 48-49 and 54), and after Carrie Chapman Catt and the National American Suffrage Association (NAWSA) advocated for women's suffrage, the 19th Amendment was passed in 1920, which prohibited gender-based discrimination.

Extreme nutritional privation and inequality stunt growth, while acute income inequality does not increase stature, indicating that a population's average stature is not as sensitive to inequality as income (Gordon, 2015, p. 83). Biological and nutritional inequality are further accentuated because males and females have genetically determined characteristics that make calories and net nutrition vary across characteristic distributions (Halsey, 2022). For example, sexual dimorphism is the pattern where men are genetically taller than females and have greater muscle mass, and the inverse relationship between stature and female body mass are around twice as large compared to men (Carson, 2012; Carson, 2018). However, sexual dimorphism extends to sex differences beyond physical size. Various techniques are developed to account for the uneven effects between calories, characteristics, and inequality, and this study uses quantile regression to evaluate varying characteristic returns across 19th and early 20th century calorie distributions.

Much of calorie variation is attributable to environmental conditions and net nutrition (Carson, 2020; Carson, 2022), and late 19th century US diets were monotonous and produced within the household (Table 2; McIntosh, 1995, p. 79). In all geographic regions, pork was the most common animal protein (Hilliard, 1972, pp. 92-111, 197, and 213; Cuff, 1993, McIntosh, 1995, p. 102; Gordon, 2015, p. 39; Floud et al 2011, p. 210). Because there were few meat preservation techniques in the early 19th century, salting and smoking were prominent (Gordon, 2015, p. 39), and sodium contributed to hypertension. Irish potatoes were a staple in the north and central US, while sweet potatoes—especially in African American diets—were dominant in the South (Hilliard, 1972, pp. 174-175; Fogel, 1974, p. 113; Fogel, 1989, pp. 132-136; Gordon, 2015, p. 40; McIntosh, 1995, p. 82; Floud et al. 2011, pp. 156-157). In 1870, the US diet compared favorably to international diets (McIntosh, 1995, p. 85; Gordon, 2015, pp. 41, 70, and 76), calories were abundant in the US, and there is little evidence of malnutrition (Carson, 2009a; Carson, 2012; Carson, 2016c; Gordon, 2015, p. 41). During the mid-19th century, a lack of refrigeration and lax food regulations allowed perishable cheese and dairy to deteriorate, and nutrition quality was compromised with unsound preservation techniques (McIntosh, 1995, pp. 79, 82, and 92; Gordon, 2015, p. 81). To increase yields and the quality of dairy products, milk was watered and whitened, and urban diets deteriorated with the separation of food consumption from food production (Cuff, 2005; Carson, 2008b; Gordon, 2015, p. 82; Komlos, 1993; Komlos et al, 1997; Hooker, 1981, p. 277).

It is against this backdrop that this study considers three questions regarding late 19th and early 20th century calorie and net nutrition variation across the calorie distribution. First, how did 19th and early 20th century calories vary by race and gender? Males required around 20 percent more calories per day than females, and although former slaves were physically more active than free whites, individuals of African descent did not require considerably more calories per day then whites. Second, across the 19th century calorie distribution, how were calories associated with socioeconomic status? Physically active laborers required more calories per day than less active white-collar workers, and physically active unskilled worker calories increased slightly across the calorie distribution but decreased for skilled workers. Third, how were calories distributed by region and over time? Individuals from the rural South and West required more calories per day than from elsewhere within the US, and across the calorie distribution, calories over time were stable and had mixed results by region.

II. Basal Metabolic Rate and Energy Accounting

Literature Review

One dietary calorie is the amount of energy required to raise a kilogram of water one degree Celsius, and during economic development, more calories per day reflect superior diets to sustain an individual (Costa and Steckel, 1995; Nordhouse, 2003, p. 20; Stauss and Thomson, 1998). Calorie distributions illustrate net nutrition variation with demographics, residence, and socioeconomic status, and this study uses age, weight, height, and physical activity to measure calories from equations with characteristics across the calorie distribution. Comparative black and white calorie estimates are important measures for historical welfare, and 18th and 19th century African-American diets maintained individuals in reasonably good nutrition and health by standards of the day (Howe, 2007, p. 58; Carson, 2009a; Floud et al, 2011, pp. 226-224, 318; Carson, 2012). However, because daily nutrition records that account for calories were not well maintained, estimating historical calories is difficult because the institutions that recorded calories were yet to develop.

During the 18th century, the British working class consumed about 2,700 calories per day, which compared favorably to 18th century French males, who only consumed around 2,400 calories per day (Fogel, 1994, p. 372; Fogel and Costa, 1997, p. 52; Floud et al. 2011, p. 56). Cuming (1940) finds that mid-19th century European-Americans consumed 3,741 calories per day, and 19th century household heads consumed 3,685 calories per day (Gordon, 2015, p. 75). Atack and Bateman (1987, p. 210) find that 19th century white males consumed around 5,000 calories per day; however, this many calories is comparable to a modern elite athlete's diet and may be difficult to justify. During the 19th century, working-class men consumed 3,100 to 3,500 calories per day, while women consumed 2,000 to 2,500 calories per day (Oren, 1973, p. 111). Carson (2016b) finds that 19th and early 20th century US white males required 3,032 and 2,975 calories per day to maintain youth and adult physical dimensions, which is supported by Putnam (2000) and Gordon (2015, pp. 63-64, Figure 3-1), who report that 19th century white workers required about 3,000 calories per day. Modern US Recommended Daily Allowances (RDA) are 3,000 calories per day for men (Garille and Gass, 2001, pp. 2-3). However, modern US calories per day are around 3,654 calories per day (Rosen, 1999, p. 14; Putnam, 2000; Shaparri, and

Rosen, 2007), which is associated with the modern obesity epidemic. Average male calories for modern Europeans is around 3,394 calories per day, while the Asian male diet provides 2,648 calories per day (Floud et al. 2011, p. 126). However, calorie estimates for women are nearly non-existent and yet to be estimated. Subsequently, 19th century US white calories were greater than 18th century Europeans and the British and sufficient to maintain weight and height in normal weight ranges but not sufficient to feed individuals to excess (Carson, 2009a; Carson, 2012; Komlos and Carson, 2017).

Access to calories and physical activity varies by race, and Alabama black males consumed around 3,270 calories per day (Higgs, 1977, p. 107). Fogel and Engerman (1974, pp. 112-113) estimate that black male slave diets averaged around 4,185 calories per day, and Sutch (1976, p. 262) finds that male slave diets averaged around 3,976 calories per day. Carson (2016a) estimates calories per day with calorie equations, and black males required around 3,050 calories per day.

Calorie Equations

From the biomedical literature and development studies, calorie equations are used to assess diets by gender and race (Floud et al. 2011, pp. 162; Rao and Raju, 2020, p. 107; Calofré-Vilà et al. 2018, p. 778). The basal metabolic rate (BMR) is the number of calories required per day by the human body to maintain a person's vital organ function at their current weight, height, age, and physical activity at rest, awake, and in a warm climate. BMR is also the basis to estimate historical calories from calorie equations (Harrison and Benedict, 1919; Floud et al. 2011, pp. 44, 72, and 75). Required calories are sensitive to the physical environment and are higher for individuals in cold climates with lean muscle mass (Poehlman et al. 1988; Poehlman et al. 1989; Koshimihi et al 2012; Williams and Woods, 2006; McLannahan and Clifton, 2008, p.

52). Other factors slow calorie requirements. For example, if calories in the future do not match calories consumed in the present, required calories in the future decrease to accommodate fewer calories (Neel, 1962; Prentice et al., 2005; Prentice et al., 2008; Speakman, 2008).

There are various equations to estimate calories required to maintain height, weight, age, and physical activity. Mifflin et al (1990, p. 247) are a set of calorie estimates that approximate calories from individual characteristics (Frakenfeld et al, 2003, pp. 1156-1159). Estimated calories are the product of the basal metabolic rate and a measure for physical activity. Mifflin et al (1990) male and female calorie equations are:

$$BMR_{Male}=5+10\times Weight\ (kgs)+6.25\times Height\ (cms)-5\times Age$$

$$BMR_{Female}=-161+10\times Weight\ (kgs)+6.25\times Height\ (cms)-5\times Age$$

These male-female Mifflin et al equations provide estimated energy requirements for resting individuals in normal to moderately overweight categories and are reasonable approximations for male and female calories (Carson, 2009a; Carson, 2012; Carson, 2016c; Carson, 2018). There is some degree of error when estimating calories from weight, height, age, and physical activity with calorie equations (Weijs et al 2007, pp. 153-156). However, Mifflin et al equations provide valuable approximations for BMRs and calories (Frakenfield et al., 2005; Floud et al., 2011, p. 314). Among other advantages, equations link calories to observable characteristics, which is not available with other estimation techniques. There is greater calorie expenditure variation among males than females; however, across the calorie distribution, 19^{th} and early 20^{th} century females required fewer calories than men (Haskey et al 2022, p. 5).

BMRs have long been used in the biomedical literature with physical measures and activity levels to estimate calories associated with weight, height, physical activity, and age (Harris and Benedict, 1919; Weijs et al. 2007; Bryne and Wilmore, 2001; Floud et al, 2011, pp.

44, 72, and 75). Nevertheless, calories—not BMRs—are the principal measure of interest for net nutrition considered in historical and development studies. Most 19th century workers were in agriculture, if only to maintain the household (Rosenbloom, 2000, p. 88; Federico, 2013, pp. 157-158; Dimitri et al. 2005; Gordon, 2015, pp. 6, 250-252), and farmers were physically more active than non-farmers (Carson, 2016b, p. 71). To approximate an individual's physical activity level (PAL), BMRs from characteristics are first sorted by occupations, and laborers are the most physically active occupation in this sample. Imputed PALs are standardized by dividing each average occupation BMR by the average labor's BMR and multiplied by the physical activity level of 1.9. Estimated calories are then calculated by multiplying imputed BMRs by active PALs by the physically active labor highest physical activity level of 1,605.975. Male white-collar and skilled imputed BMR values of 1,583.134, and white-collar skilled male PALs is 1.9*.9858 or 1.873. Male workers with no listed occupations are 1,603.717.

Because modern activity levels are lower than historical activity levels, using modern calorie equations is less accurate than if historical equations were available for historical populations, who were more physically active, and lean body mass requires more calories per day to sustain physical activity and withstand infectious diseases (McKeown, 1962; McKeown and Record, 1962; Meeker, 1976; Floud et al, 2011, pp. 42, 146, 162 and 347; Steckel and Kjellstöm, 2019, p. 77; Marques et al, 2019, p. 152). Some evidence indicates predictive calories for individuals of African and European ancestry are comparable, recent studies indicate Mifflin et al predictive calories equations may systematically overestimate daily calorie requirements for individuals of African decent (Reneau et al, 2019, pp. 5-8), and there may be no measurable calorie difference between individuals of African and European decent.

III. Demographics, Socioeconomic Status, Residence, and 19th Century Females and Males

To evaluate 19th and 20th century height, weight, and net nutrition, institutions and processes would ideally collect samples from randomly collected historical sources. These historical samples are, unfortunately, not available. In the absence of randomly collected data, military and prison records are two historical sources that recorded weight and height (Fogel et al. 1978; Fogel et al 1979). Common concerns with military records are minimum stature requirements for service (Sokoloff and Viloflour, 1982; Komlos and Kim, 1990, pp. 117-118), and military records underrepresent women, individuals of African descent, and other minorities. Military stature enforcement and weight requirements may have also varied over time with access to military recruits. Alternatively, prison records reflect conditions among the working-class, that segment of society most affected by biological change; however, there are inmates with higher socioeconomic status in the prison sample (Sokoloff and Viloflor, 1982, p. 457, Figure 1; A'Hearn, 2004). Prison entry requirements may have varied over the business cycle. Nonetheless, prison weight and height are consistent with other late 19th and early 20th century records (Margo and Steckel, 1982; Steckel, 1979; Nicholas and Steckel, 1991, pp. 941-943; Floud et al. 2011).

Data used in this study are part of a large 19th and early 20th century prison data sample. Between 1860 and 1940, prison enumerators recorded gender, complexion, age, period received, height, weight, nativity, pre-incarceration occupation, and crime in prison registries. There was care when recording weight and height values because physical descriptions had legal implications in the event individuals escaped and were recaptured. Physical descriptions also helped identify individuals within prisons. All state prison depositories were contacted on multiple occasions, and affordable and available records are entered into a master data set. Data collected for this project are from 19th and early 20th century US prisons and include Arizona, Colorado, Idaho, Illinois, Kentucky, Missouri, Mississippi, Montana, Nebraska, New Mexico, Oregon, Eastern Pennsylvania, Western Pennsylvania, Philadelphia, Tennessee, and Texas prisons. Records consist of 172,277 males and 4,592 females for a total of 176,869 records. Subsequently, female records comprise approximately 2.5 percent of the prison sample.

Prison enumerators recorded physical characteristics at the time individuals were incarcerated and represent pre-incarceration conditions and not conditions within prisons. Complexions were recorded across prison samples, and individuals of European descent were recorded as white, light, medium, and dark. Individuals of African ancestry were recorded as negro, black, light black, and dark black. There was a high proportion of individuals of combined European and African ancestry recorded as 'mulattos.' However, in the results that follow, 'mulatto' complexions are classified as mixed race. At least for a time, the Arizona and Montana prisons recorded a photograph with written complexions, and it is clear from prison photographs that individuals classified as blacks were of African ancestry, while inmates classified as whites were of European ancestry. There were also individuals with Mexican Mestizo ancestry in the sample (Carson, 2005; Carson, 2007).

Occupations were classified broadly and in detail. Merchants, bankers, and high skilled workers are classified as white-collar workers. Blacksmiths, tailors, and carpenters are classified as skilled workers. Because women were generally not farmers, male farmers are excluded from this study. Prison records did not distinguish between common and farm laborers, and in the results that follow, common and farm laborers are combined as unskilled workers. This unskilled laborer aggregation upwardly biases common laborer's net nutrition and downwardly biases agricultural workers. Workers without legible or recorded occupations are classified with no occupations.

Table 1. 19th and 20th Century Demographics, Socioeconomic Status, Nativity, and Residence

	Frequency	*Percent*		*Frequency*	*Percent*
Gender			**Race**		
Female	4,592	2.60	Black	41,299	23.35
Male	172,277	97.40	Mexican	6,710	3.79
Total	176,869	100.00	Mulatto	27,255	15.41
Residence			White	101,605	57.45
Arizona	4,056	2.29	**Nativity**		
Colorado	6,021	3.40	*United States*		
Idaho	691	.39	Far West	3,915	2.21
Illinois	11,818	6.68	Great Lakes	15,697	8.87
Kentucky	11,640	6.58	Middle Atlantic	24,491	13.85
Missouri	19,688	11.13	Northeast	1,962	1.11
Mississippi	1,732	.98	Plains	20,733	11.72
Montana	9,118	5.16	Southeast	57,978	32.78
Nebraska	7,476	4.23	Southwest	29,072	16.44
New Mexico	3,057	1.73	*International*		
Oregon	2,192	1.24	Canada	1,610	.91
PA, Est	9,178	5.19	Europe	9,488	5.36
PA, West	7,867	4.45	Great Britain	5,189	2.93
Philadelphia	9,073	5.13	Latin America	6,734	3.81
Tennessee	29,268	16.55	**Observation Decade**		
Texas	43,994	24.87	1860s	2,613	1.48
Ages			1870s	14,899	8.42
Teens	25,441	14.38	1880s	26,196	14.81
20s	89.515	50.61	1890s	34,397	19.45
30s	37,673	21.30	1900s	47,037	26.59
40s	15,787	8.93	1910s	42,482	24.02
50s	6,403	3.62	1920s	6,462	3.65
60s	2,050	1.16	1930s	2,783	1.57
Occupations					
No Occupations	26,572	15.02			
Unskilled	99,049	56.00			

White-Collar and Skilled	51,248	28.98

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; Idaho State Archives, 2205 Old Penitentiary Road, Boise, Idaho 83712; Illinois State Archives, Margaret Cross Norton Building, Capital Complex, Springfield, IL 62756; Kentucky Department for Libraries and Archives, 300 Coffee Tree Road, Frankfort, KY 40602; Missouri State Archives, 600 West Main Street, Jefferson City, MO 65102; William F. Winter Archives and History Building, 200 North St., Jackson, MS 39201; Montana State Archives, 225 North Roberts, Helena, MT, 59620; Nebraska State Historical Society, 1500 R Street, Lincoln, Nebraska, 68501; New Mexico State Records and Archives, 1205 Camino Carlos Rey, Santa Fe, NM 87507Oregon 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; 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.

Table 1 presents descriptive statistics for gender, residence, age, occupations, race, nativity, and observation decade. There are more men relative to women in the prison sample than the general population, and whites in the sample are more common than other racial groups. However, black males are overrepresented in the prison sample relative to the general population. Women were a small portion of the prison sample (Table 1), and black women are overrepresented in the prison sample relative to the general population (Steckel, 2000; Haines, 2000). Within the prison sample, Texas, Tennessee, and Missouri are the most common nativities. Incarceration is sensitive to age, and individuals in their 20s and 30s were the mostly likely to commit crimes and be incarcerated (Gottfredson and Hirschi, 1990; Hirschi and

Gottfredson, 1983). Prison conditions reflect a diverse set of socioeconomic status, and over half of the sample was unskilled, while nearly 30 percent of the male prison sample's occupations were skilled or white-collar occupations (Rosenbloom, 2002, p. 88, Carson, 2008a; Carson, 2009a). Nearly half of the sample was born in the South, and there is a sizeable portion from the Plains and Middle-Atlantic states. Europeans were the most common immigrants, followed by Latin Americans, British, and Canadians, who were less likely to migrate South and be incarcerated in US prisons (Hooker, 1981, pp. 208-209; Gordon, 2015, p. 36). The most common incarceration decade was the 1900s; however, there were individuals observed as early as the 1860s and as late as the 1930s.

Table 2, Male and Female Calorie Distributions

Quantile	*Male*	*Female*
Mean	3,025.77	2,479.56
Median	3,024.75	2,467.99
Standard Deviation	226.35	239.44
Skewness	.0387	.4398
Kurtosis	3.365	4.406
5th	2,657.27	2,108.06
10th	2,741.97	2,196.14
25th	2,877.11	2,330.93
50th	3,024.75	2,467.99
75th	3,173.67	2,615.17
90th	3,310.67	2,771.86
95th	3,398.83	2,882.87
99th	3,569.92	3,171.54
Gini Coefficient	.04191	.05301

Source: See Table 1.

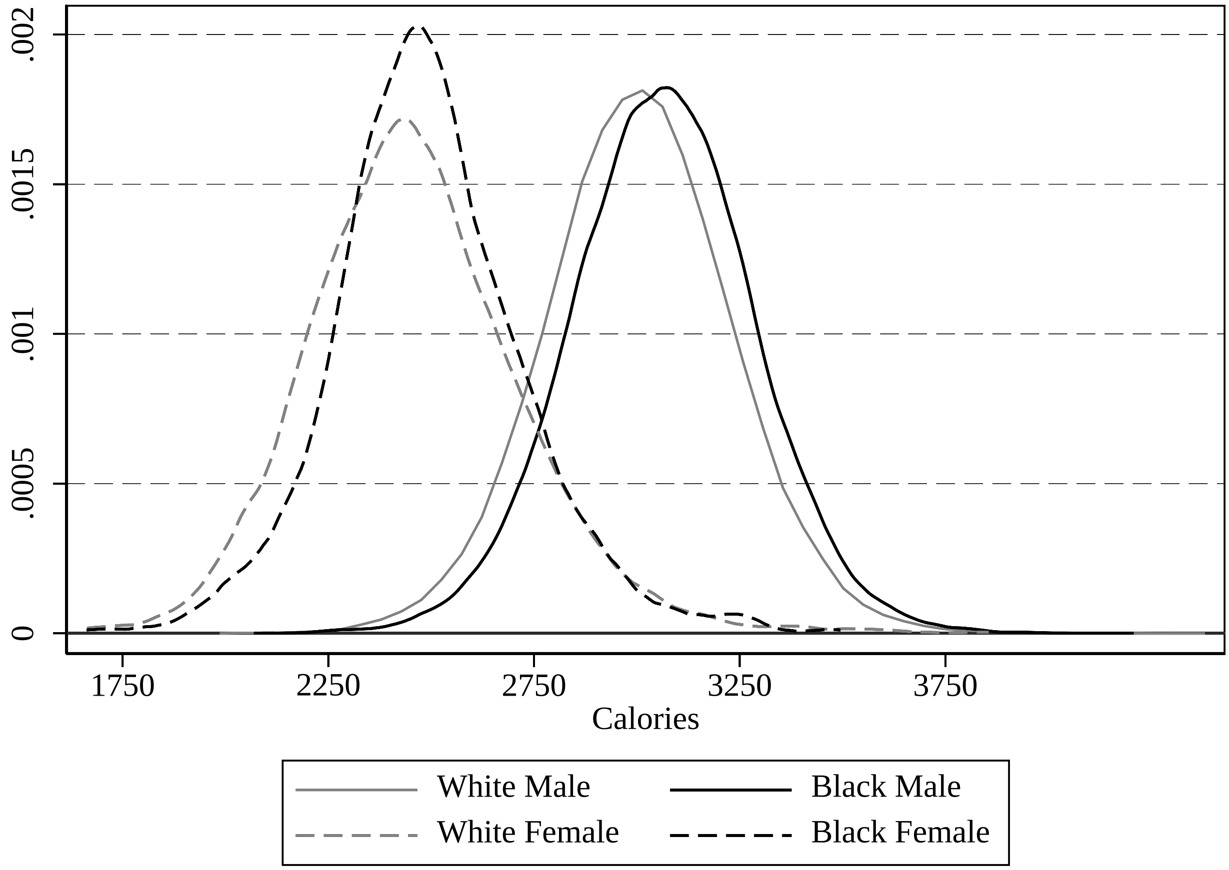

Figure 1, Black and White, Female and Male Body Mass

Source: See Table 1.

Late 19th and early 20th century calorie distributions are essential in assessing net nutrition, economic welfare, and health, and Mifflin et al. equations offer insight into how calories were distributed (Mifflin et al. 1990; Calofré-Vilà,et al. 2018). Figure 1 presents male and female calorie distributions, which were distributed symmetrically. Using contemporary calorie equations, late 19th and early 20th century male BMRs were between 1,350 to 2,000 calories per day and between 1,000 and 1,600 per day for females (Table 2; Harris and Benedict, 1919; Floud et al. 2011, pp. 109-111, Tables 3.3 and 3.4). Average black and white male calories were 3,065.65 and 3,005.56, and average black and white female calories were between 2,495.21 and 2,460.63.

Gini Coefficients are an important measure to assess calorie distributions within a population (Floud et al. 2011, p. 94), and black and white male calorie Gini Coefficients were .0404 and .0422. Black and white female calorie Gini Coefficients were .0496 and .0581, indicating there was greater caloric inequality among women. Subsequently, males received greater calories per day than females, blacks required more calories than whites, white female calories were distributed less equitably than black female calories, and male calories were distributed more equally than women.

IV. Characteristics and Nutrition across the Basal Metabolic and Calorie Diminution

Quantile regression functions are now constructed to evaluate nutritional effects by characteristics across BMR and calorie distributions (Koenker and Bassett, 1982; Hendricks and Koenker, 1992). Let y_i represent BMRs and calories for the i[th] individual and x_i equal a vector of covariates representing gender, race, age, occupation, demographic, and period received. The quantile function is

$$y_i^p = Q_y\left(p \middle| x\right)^p = \theta^p x_i + \varepsilon_i^p,\ p \in (0,1)$$

which is the p^{th} BMR and calorie quantile, given x_i. The interpretation of the β_i^p coefficient is how BMR and calorie response variables change relative to the x_i dependent variable when x_i changes by one unit at the p^{th} quantile. For example, $\beta_{age}^{.75}$ is how BMRs and calories change at the 75[th] centile when age increases by one year. The use of quantile estimation offers advantages over least squares estimates, which includes more robust estimation in the face of an unknown truncation point and a more complete description of characteristic effects on the BMR and calorie distributions (Komlos and Kim, 1990)

$$BMR_i^p = \alpha^p + \beta_i^p Gender_i + \sum_{R=1}^{2} \beta_R^p \, Race_i + \beta_A^p Age_i + \sum_{j=1}^{2} \beta_j^p Occupation_i + \sum_{n=1}^{10} \beta_n^p Nativity_i$$

$$+ \sum_{r=1}^{10} \beta_r^p \, \mathrm{Re}\, sidence_i + \sum_{t=1}^{5} \beta_t^p \, \mathrm{Re}\, ceived_i + \varepsilon_i^p$$

and

$$Calories_i^p = \alpha^p + \beta_i^p Gender_i + \sum_{R=1}^{2} \beta_R^p \, Race_i + \beta_A^p Age_i + \sum_{j=1}^{2} \beta_j^p Occupation_i + \sum_{n=1}^{10} \beta_n^p Nativity_i$$

$$+ \sum_{r=1}^{10} \beta_r^p \, \mathrm{Re}\, sidence_i + \sum_{t=1}^{5} \beta_t^p \, \mathrm{Re}\, ceived_i + \varepsilon_i^p$$

A female dummy variable is included to account for calorie variation by gender. Race dummy variables are included for African-Americans, mixed-race, and Mexican complexions. A continuous age variable is included to account for calories required by age to maintain weight and height across the calorie distribution. Occupation dummy variables are included to evaluate calorie variation by socioeconomic status. Nativity dummy variables are included to account for BMR and calorie variation by early life conditions across distributions, while residence variables are included to assess calorie variation by regional access to calories. There are two ways to interpret net nutrition variation over time. Measured in the current period, BMRs and calories reflect the current net nutrition encountered by diverse cohorts at the time of measurement. Measured since birth, net nutrition and calories reflect how the same cohort's cumulative net nutrition varied since birth. Because the purpose here is to determine BMR and calorie variation across the distribution in the current period, observation period dummy variables are included in BMR and calories models (Carson, 2019, p. 32).

Tables 3 and 4, Model 1 present BMR and calorie quantile estimates for men and women in the 19th and early 20th century United States. Models 2 through 9 illustrate calorie variation across the distribution related to demographics, socioeconomic status, and observation period.

Table 3, Basal Metabolic Rate across Quantiles by Demographics, Socioeconomic Status, Nativity, and Residence

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Total	5th	10th	25th	50th	75th	90th	95th	99th
Intercept	1703.87***	1554.01***	1585.09***	1640.49***	1701.27***	1761.92***	1819.42***	1859.57***	1899.98***
Gender									
Male	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Female	-294.39***	-298.25***	-299.10***	-302.46***	-302.37***	-297.74***	-273.44***	-263.95***	-221.06***
Race									
Black	2.59***	-4.48***	-1.92	.146	4.25***	6.25***	8.31***	6.74***	2.63
Mulatto	1.95**	-4.82***	-3.92**	-.497	2.14**	6.76***	8.69***	4.80***	-5.85
Mexican	-49.18***	-44.18***	-44.36***	-43.38***	-48.04***	-52.59***	-49.99***	-54.87***	-64.76***
White	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Age	-3.45***	-3.93***	-3.90***	-3.82***	-3.56***	-3.21***	-2.73***	-2.33***	-.889***
Occupation									
White Collar and Skilled	-4.06***	-1.52	-3.00***	-4.03***	-3.81***	-4.50***	-5.29***	-5.00**	-6.45**
Unskilled	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
No Occupation	-10.25***	-15.83***	-12.10***	-10.81***	-8.95***	-9.40***	-8.02***	-9.17***	-11.95**
Nativity									
International									
Canada	-5.26	-8.70	-7.16	-4.45	-4.11	-1.04	-9.84	-11.10	-15.34
Europe	-12.94***	-17.55***	-13.39***	-11.75***	-13.35***	-10.59***	-10.97**	-18.49***	-10.42
Great Britain	-18.97***	-17.99***	-16.84***	-18.25***	-18.94***	-15.28***	-22.67***	-29.62***	-32.96**

Latin America	-28.33***	-21.44***	-19.82***	-23.90***	-18.39***	-28.10***	-35.15***	-43.92***	-30.73*
National									
Northeast	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle Atlantic	-6.25**	-6.56	-3.71	-5.80	-6.81**	-3.62	-8.79**	-17.47***	-6.44
Great Lakes	10.41***	7.82**	12.40***	11.17***	8.87**	9.26**	11.91***	6.42	18.64
Plains	16.70***	16.12***	19.79***	17.73***	15.40***	17.44***	15.88***	8.02	26.22*
Southeast	19.09***	14.47***	19.01***	21.11***	19.77***	20.93***	17.29***	11.74	30.22**
Southwest	18.23***	12.62***	14.35***	17.27***	18.20***	22.05***	19.19***	12.20	37.39***
Far West	10.07***	12.17**	14.68***	11.55***	8.95**	14.33***	9.64**	-1.18	.952
Residence									
Arizona	-25.38***	-27.61***	-28.36***	24.44***	-24.50***	-25.53***	-24.47***	-28.90***	-34.56***
Colorado	-6.59***	-7.61**	-6.13**	-4.83**	-4.34**	-6.45**	-11.47***	-10.56***	-12.39
Idaho	3.68	8.25	-1.85	2.69	1.27	3.13	-6.24	4.78	4.29
Illinois	-17.02***	-21.42***	-21.75***	-19.44***	-17.70***	-15.93***	-12.85***	-10.85***	-3.09
Kentucky	-40.68***	-46.78***	-46.43***	-42.51***	-39.83***	-39.84***	-35.99***	-37.85***	-39.54***
Missouri	-38.67***	-38.72***	-40.89***	-39.13***	-38.19***	-37.53***	-39.22***	-40.66***	-43.49***
Mississippi	-6.03**	-9.21**	-9.86**	-6.42*	-4.35*	-2.46	-9.07**	-14.18**	-16.43
Montana	40.93***	38.33***	38.13***	43.08***	43.45***	41.65***	37.89***	37.82***	46.27***
Nebraska	-27.26***	-29.00***	-27.50***	-26.45***	-24.82***	-25.95***	-30.52***	-30.95***	-29.14***
New Mexico	-2.33	-5.26*	-6.81**	-.822	1.52	-.790	-4.62	-3.94	-14.02
Oregon	-.903	-7.00	-7.10**	-1.54	-.396	-.447	.014	1.15	15.85
PA, East	-48.53***	-48.19***	-50.40***	-49.02***	-48.36***	-49.08***	-49.50***	-48.97***	-30.49***
PA, West	-11.78***	-10.45***	-15.58***	-14.65***	-12.88***	-11.92***	-8.69**	-10.36***	-2.14
Philadelphia	-42.58***	-38.69***	-40.52***	-38.87***	-43.60***	-46.07***	-46.87***	-49.15***	-45.66***
Tennessee	-19.62***	-20.18***	-20.34***	-19.57***	-20.35***	-19.81***	-19.94***	-17.74***	-11.78**
Texas	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Received									
1860s	28.12***	11.87**	19.33***	27.89***	30.44***	39.00***	27.97***	24.88***	11.15

1870s	18.99***	14.37***	18.83***	19.05***	20.14***	20.47***	21.44***	19.63***	13.21**
1880s	10.18***	3.62**	11.10***	11.99***	12.26***	10.69***	10.96***	10.30***	-4.88
1890s	6.45***	9.75***	9.93***	7.11***	6.71***	5.12***	5.90***	6.21***	2.77
1900s	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1910s	.347	2.03	1.55	.261	.778	-1.26	-.941	-193	-1.28
1920s	9.54***	5.13	8.20***	7.36***	8.22***	8.70***	13.61***	17.39***	26.54***
1930s	24.30***	15.02***	17.00***	18.88***	23.38***	24.80***	33.83***	35.90***	60.88***
N	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869
R^2	.2629	.2572	.2235	.1722	.1299	.0985	.0746	.0604	.0424

Source: See Table 1.

Note: Standard errors clustered on age. *** Significant at .01.; ** significant at .05; significant.

Table 4, Calories across Quantiles by Demographics, Socioeconomic Status, Nativity, and Residence

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 4*	*Model 5*	*Model 6*	*Model 7*	*Model 8*
	Total	5th	10th	25th	50th	75th	90th	95th	99th
Intercept	3226.84***	2944.55***	3005.57***	3107.70***	3224.61***	3336.83***	3453.17***	3522.81***	3601.11***
Gender									
Male	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Female	-566.55***	-573.55***	-574.02***	-584.09***	-583.77***	-572.80***	-578.57***	-504.00***	-415.57***
Race									
Black	8.93***	-1.42	.718	2.88**	11.68***	15.15***	20.18***	17.62***	10.53
Mulatto	6.82***	-4.70*	-5.15*	2.43	7.64***	15.28***	10.90***	14.03***	-2.79
Mexican	-90.90***	-81.65***	-83.47***	-79.71***	-89.97***	-97.15***	-96.12***	-98.40***	-115.39***
White	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Age	-6.60***	-7.53***	-7.44***	-7.28***	-6.86***	-6.15***	-5.31***	-4.52***	-1.81***
Occupation									
White Collar and Skilled	-42.73***	-31.93***	-36.14***	-40.27***	-42.36***	-45.74***	-49.24***	-49.91***	-50.53***
Unskilled	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
No Occupation	-19.33***	-27.86***	-20.97***	-20.30***	-16.70***	-17.21***	-16.61***	-18.11***	-21.00**
Nativity									
International									
Canada	-9.82	-25.66**	-20.99**	-14.76	-6.61	1.23	-19.01	-11.94	-17.20
Europe	-22.98***	-37.91***	-27.32***	-22.32***	-23.50***	-15.39**	-21.11**	-30.90***	-16.36

Great Britain	-33.63***	-34.55***	-33.98***	-34.58***	-31.68***	-23.04***	-40.44***	-52.64***	-53.47*
Latin America	-48.07***	-40.30***	-36.61***	-42.18***	-46.83***	-47.36***	-64.72***	-79.09***	-57.15*
National									
Northeast	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Middle Atlantic	-10.83**	-14.90*	-10.51*	-10.73	-11.12**	-3.35	-17.49**	-30.59*	-11.40
Great Lakes	21.41***	11.95	21.44***	20.93***	19.83***	22.92***	21.92***	15.04	42.64
Plains	34.81***	30.87***	37.08***	35.45***	31.62***	39.07***	32.15***	21.21	50.92*
Southeast	39.74***	26.04***	34.22***	40.92***	41.59***	46.29***	35.36***	26.92	61.46**
Southwest	39.56***	26.23***	27.93***	36.31***	39.67***	48.78***	37.84***	29.07*	75.23***
Far West	21.90***	17.87*	27.61***	36.31***	20.20***	34.90***	18.81*	2.27	-.690
Residence									
Arizona	-47.12***	-51.34***	-53.03***	-44.30***	-45.81***	-47.48***	-43.71***	-51.71***	-63.03***
Colorado	-13.55***	-17.94***	-16.01***	-9.51**	-10.38***	-15.55***	-21.07***	-21.43**	-20.49
Idaho	8.31	10.68	-.800	6.32	6.31	3.50	-11.91	7.55	-9.67
Illinois	-33.55***	-39.49***	-42.15***	-38.21***	-35.16***	-31.14***	-28.89***	-20.36***	-5.54
Kentucky	-74.93***	-82.32***	-84.78***	-76.73***	-73.00***	-79.84***	-68.06***	-69.98***	-72.03***
Missouri	-72.87***	-73.01***	-77.23***	-74.16***	-71.14***	-71.58***	-75.85***	-77.26***	-86.53***
Mississippi	-10.20***	-14.98***	-19.95***	-10.39	-7.62	-4.35	-18.74**	-24.57*	-35.14
Montana	79.18***	77.36***	71.94***	80.70***	84.42***	77.94***	73.05***	73.93***	94.14***
Nebraska	-52.67***	-57.33***	-54.65***	-49.62***	-49.75***	-52.93***	-59.26***	-56.14***	-51.34***
New Mexico	-4.30	-10.40	-13.92**	-3.55	2.81	-3.07	-6.42	-6.12	-19.96
Oregon	-.881	-7.94	-14.48**	1.45	.377	.162	.119	2.48	34.10
PA, East	-91.49***	-92.02***	-95.79***	-91.74***	-90.96***	-93.62***	-94.79***	-92.14***	-60.55***
PA, West	-22.54***	-21.47***	-31.41***	-28.72***	-23.77***	-21.97***	-17.06***	-17.66***	-8.34
Philadelphia	-82.50***	-73.88***	-76.24***	-75.90***	-84.30***	-89.44***	-91.79***	-91.98***	-88.09***
Tennessee	-40.36***	-39.47***	-41.45***	-38.72***	-41.77***	-41.73***	-40.91***	-35.35***	-26.81**
Texas	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference

Received									
1860s	55.09***	22.41**	39.64***	54.11***	58.87***	73.86***	53.31***	50.82***	21.54
1870s	37.33***	29.60***	35.56***	37.39***	39.64***	40.65***	41.51***	39.10***	26.72***
1880s	20.26***	9.70***	21.41***	23.73***	23.42***	21.74***	21.17***	19.47***	-8.89
1890s	12.61***	19.74***	19.05***	13.68***	11.98***	10.37***	10.31***	13.31**	6.25
1900s	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
1910s	-.724	3.93	1.51	.126	-.055	-3.79**	-2.49	-.192	-6.81
1920s	16.55***	16.74**	13.77***	13.71***	15.30***	14.99***	22.84***	30.93***	37.23***
1930s	43.09***	30.53***	32.16***	32.25***	41.61***	44.90***	59.49***	67.74***	115.97***
N	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869	176,869
R^2	.2738	.2607							
F	1439.89								

Source: See Table 1.

Note: Standard errors clustered on age. *** Significant at .01.; ** significant at .05; significant.

Three paths of inquiry are considered when evaluating 19th and early 20th century female and male BMRs and calories. First, across distributions, males required more calories per day than females because men—on average—have greater muscle per unit of tissue mass and were more physically active than females (Bleakley and Costa, 2013, pp. 5-10). Sexual dimorphism is the biological and genetic difference between females and males, and females require about 20 percent fewer calories per day than men (Chen, Huq, and D'Souza, 1981, p. 61). For a contemporary US comparison for physical measures, adult males are about nine percent taller and 16.5 percent heavier than females (US NHANES, 1999-2002), and these genetic differences extend to nutrition. Males are also physically more active than females and their occupations were outdoors in physically demanding conditions, which is associated with greater male calories (Church et al., 2011; Gordon, 2015, p. 54). BMRs and calories vary by gender across the calorie distribution and illustrate biological inequality and returns to net nutrition were significantly higher for women (Figure 2; Tables 3 and 5). For example, at the 5th centile, female calorie returns were around 573 calories less than men. However, female net nutritional returns at the 99th centile were 416 calories less than males (Figure 2). Subsequently, calories were related to gender, and women in higher net nutritional status had higher returns to nutrition than women in lower nutritional categories.

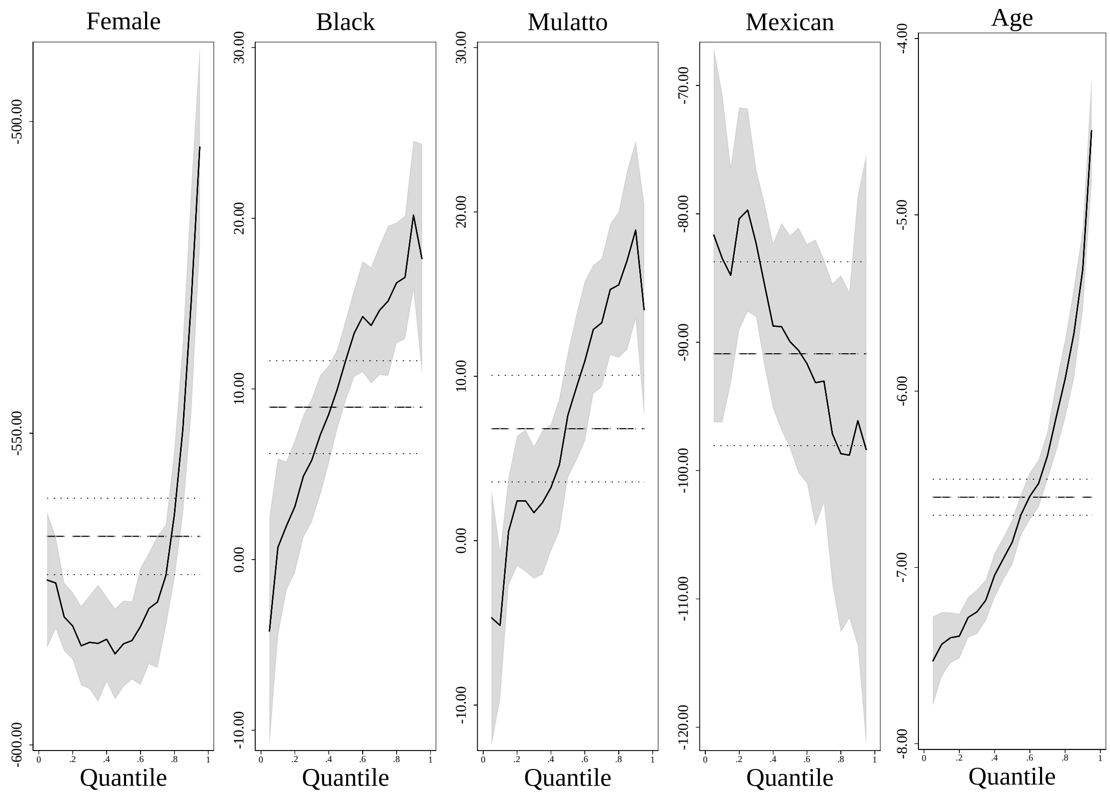

Figure 2, Calories across Genders, Race, and Age

Source: See Table 4.

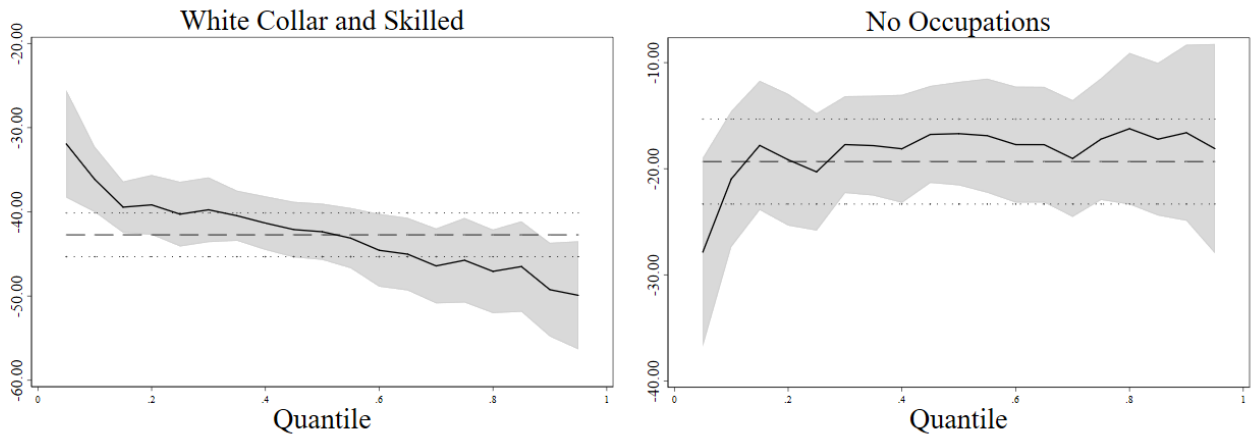

Figure 3, Calories across the Calorie Distribution by Socioeconomic Status

Source: See Table 4.

Calories vary with race and complexion, and African-Americans have shorter average stature than fairer complexioned whites (Steckel, 1979; Carson, 2009), individuals with darker complexions required more calories per day. (Figure 2; Carson, 2015d). However, 19th century blacks were shorter and had higher BMIs (Steckel, 1979, p. 374; Margo and Steckel, 1992, 511, Table 24.2; Carson, 2020b; Carson, 2015b; Fogel, 1989, pp. 138-142, Table 25), indicating that blacks were shorter but received comparable diets and had similar calorie allocations during adulthood. There is also greater protein in darker complexioned muscle tissue, and protein requires more calories per day (Schutte et al1984; Aloa et al. 1997; Barrondess et al 1997; Wagner and Hayward, 2000).

Second, calories varied by socioeconomic status, and across the distribution, physically active unskilled workers had higher BMRs and required more calories per day to maintain weight and net nutrition (Figure 3; Carson, 2016c). The relative composition between BMRs and BMIs illustrate an individuals' physical activity (Table 3), and an individual is in better physical conditions if BMIs and BMRs are high, while an individual with a low BMR and high

BMI is physically less active and less healthy (Jette et al 1990; Pellet, 2000). Occupations reflect socioeconomic status, and unskilled workers and farmers had greater BMRs and BMIs, indicating they were physically more active than workers in other occupations who required fewer calories per day (Figure 3; Table 3; McIntyre, 1995, pp. 93-94; Carson, 2012; Carson, 2021). On the other hand, white-collar and skilled workers were removed from rural agricultural diets, were physically less active, and required fewer calories per day to maintain their physical size (Table 4), indicating unskilled workers were in better nutritional conditions and more physically active than white-collar and skilled workers. Returns to white-collar and skilled calories also decreased across the calorie distribution, while the effect of no listed occupation increased across the calorie distributions (Figure 3). In sum, physically active unskilled workers were physically more active and required more calories per day across the calorie distribution than workers in other occupations, while skilled workers had diminishing returns to higher socioeconomic status, and there was increasing returns across the distribution for workers without occupations.

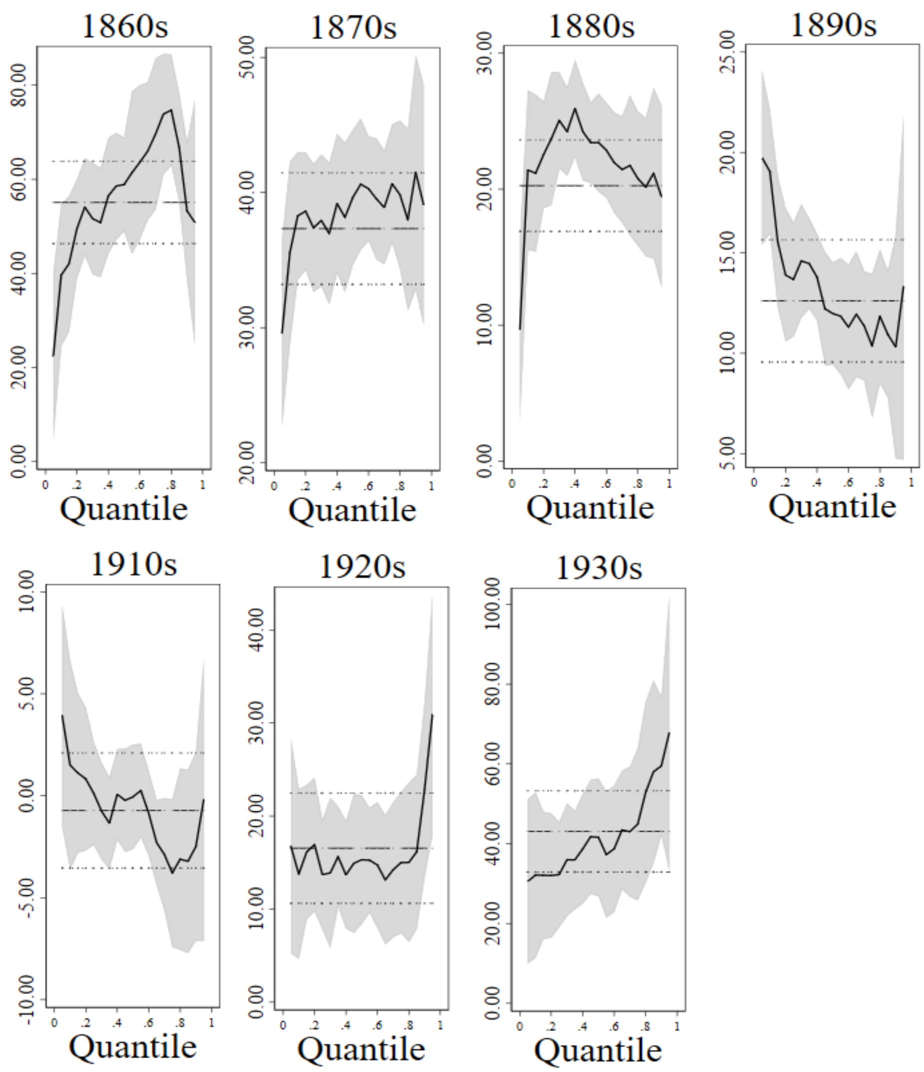

Figure 4, Calories across Observation Period Quantiles

Source: See Table 4.

Third, calories varied by residence across the distribution, and individuals in rural states consumed more calories per day than workers in urban regions (Figure 4; Hilliard, 1972, pp. 62-69; Fogel and Engerman, 1974, pp. 109-115, Figures 33 and 34; Fogel, 1989, pp. 132-138; Fogel, 1994, p. 36; Bodenhorn, 1999, p. 988; McIntosh, 1995, pp. 91-93). Individuals in the South and West had greater access to diverse and abundant diets, which includes staple grains, corn, pork, beef, and feral game (Figure 4; Hilliard, 1972, pp. 62-63; Comer, 2000, p. 1311; Floud et al 2011, pp. 208-212) and were lower in the upper South, which was agriculturally less productive than the New South. Calories were lowest in the urban, industrialized Northeast (Cuff, 2005; Craig, Goodwin and Grennes, 2004; Carson, 2008b, p. 349). Northeast industrialization separated farm production from consumption, and urban residents were further removed from rural dairy, where net nutrition was compromised when it was transported to urban areas in metal containers (Carson, 2008b, pp. 363-368; Carson, 2016b; Cochrane, 1977, p. 72; Shergold, 1982, pp. 185-189; Popkin, 1993, pp. 145-146; Comer, 2000, p. 1311). Urban diets in industrialized 19th century Philadelphia and Pennsylvania included more processed foods that were tainted by milk watering, which hastened spoilage (Fletcher, 1955; Levy, 2021, p. 116; Carson, 2008b, p. 349; Gordon, 2015; McIntosh, 1995, pp. 84 and 89). Pennsylvania farmers also fed whiskey mash to cows, which further deteriorated urban diets (Cuff, 2005). Access to milk and dairy varied throughout the US; however, because of higher temperatures and limited refrigeration and transportation systems, Southern dairy productivity lagged elsewhere within the US (Hilliard, 1972, pp. 122-135; McIntosh, 1995, p. 85). Subsequently, 19th century diets varied by residence, and across their daily calorie distributions, physically more active individuals, residence in the South, West, and rural states required more calories per day than workers in sedentary occupations in Northeastern urban areas.

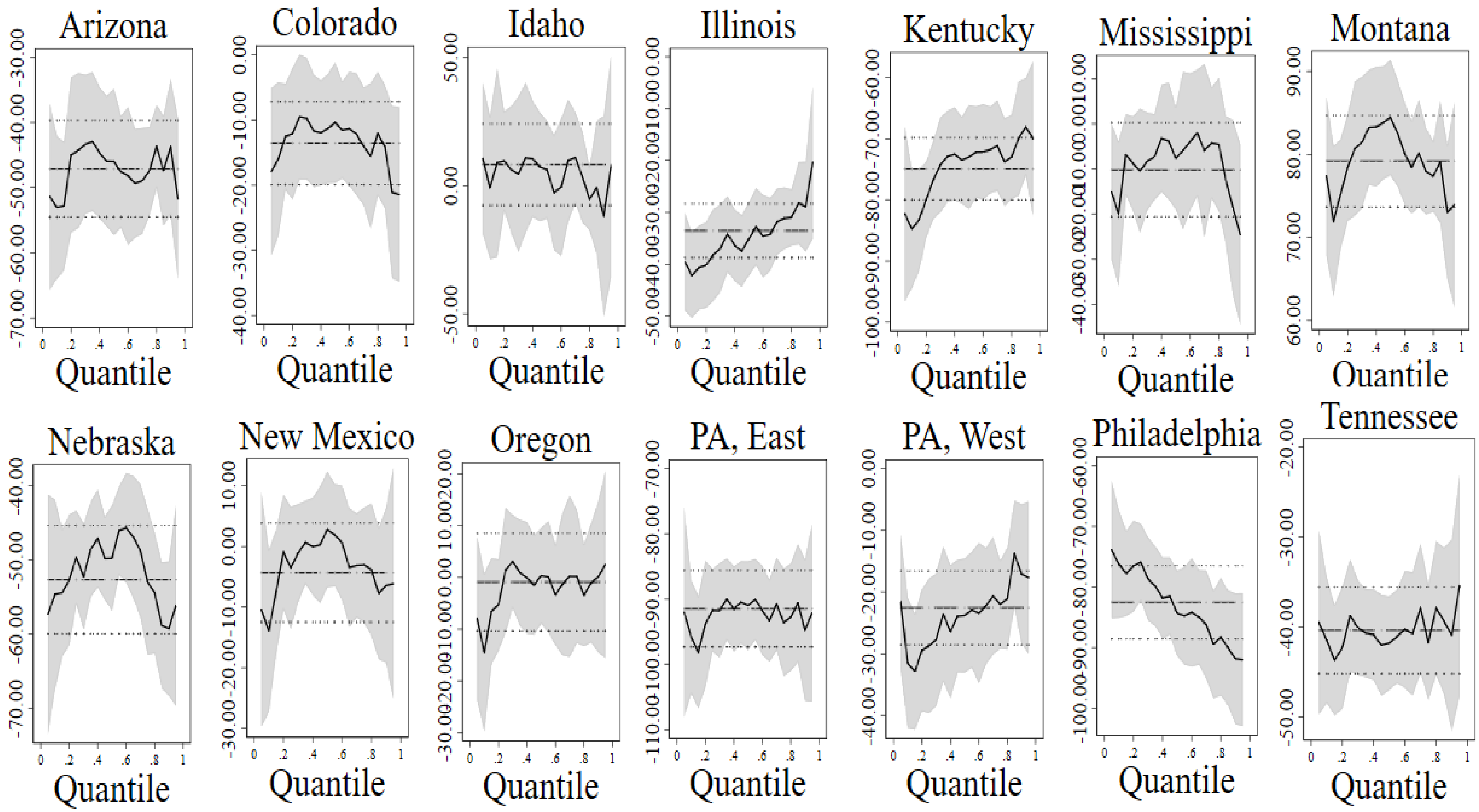

Figure 5, Calories across State of Residence

Source: See Table 4.

V. Conclusion

When pecuniary income and wealth are not available or only measured with collectively held household resources, calories per day are an important measure to assess net nutritional conditions. Mifflin et al and calorie equations offer important insight into calculating 19th and early 20th century net nutrition. Across the 19th century calorie distributions, men required more calories per day than women, and calorie returns by socioeconomic status for women increased across the calorie distribution. During the late 19th and early 20th century, men were also more attached to the paid labor force, where greater physical activity was required. The number of calories required is positively related to lean muscle mass, and men, on average, have greater muscle mass than women and require more calories. Calories may have been higher for darker complexioned individuals; however, darker complexioned individuals have shorter statures, indicating part of greater required calories for darker complexioned individuals is related to greater muscle tissue. Workers in physically active occupations required more calories per day than physically less active white-collar and skilled occupations. Unskilled workers were more physically active and required more calories per day than white-collar and skilled workers. Calories were also related to residence, and individuals in the West and South receive more calories per day than elsewhere within the US, and workers in urban areas received fewer calories per day than rural areas. Subsequently, BMR and calories per day varied across distributions by gender, race, socioeconomic status and residence, and greater net nutrition within the household was allocated to males relative to women.

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