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CRIME AND BODY WEIGHT IN THE NINETEENTH CENTURY: WAS THERE A RELATIONSHIP BETWEEN BRAWN, EMPLOYMENT OPPORTUNITIES AND CRIME?

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ABSTRACT

This paper considers the extent to which crime in the 19th century was conditioned on body weight. With data on inmates incarcerated in the Tennessee and Illinois state penitentiaries between 1831 and 1892, we estimate the parameters of Wiebull proportional hazard specifications of the individual crime hazard. Our results reveal that consistent with a theory in which body weight can be a source of labor market disadvantage, crime in the 19th century does appear to have been conditioned on body weight. However, in contrast to the 20th century, in which labor market disadvantage increases with respect to body weight, in the 19th century labor market disadvantage decreased with respect to body weight, causing individual crime hazards to decrease with respect to body weight. We find that such a relationship is consistent with a 19th century complementarity between body weight and typical jobs that required adequate nutrition and caloric intake to support normal work effort and performance.

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1. Introduction

Although early attempts by criminologists to link criminal propensities with physical attributes have been discredited, modern economic studies have linked such propensities with weight and attractiveness (Price 2009; Mocan and Tekin 2006). What separates the modern economic approach from earlier approaches is that economists do not offer deterministic explanations in that certain features are associated with inherent criminal tendencies. Rather, economists posit a connection between individual physical attributes, labor market opportunities, and the expected rewards of criminal activity.

This paper employs previously unexploited data from two nineteenth century penitentiaries to investigate the association between body weight and the age at which an individual enters into criminal activity. We follow the approach laid out in Price (2009) who argues that being overweight is consistent with an increased probability of entering into criminal activity due, in part, to having fewer and less remunerative legitimate job market opportunities. Unlike the twentieth-century experience in which obesity is associated with greater probability of criminal activity, we find that relatively heavy individuals in the nineteenth century had lower probabilities of criminal activity at every age. We offer two explanations for this phenomenon. First, most weight-for-height measures, such as the body mass index (BMI) [1], cannot distinguish between those who are overweight due to excess body fat and those who are overweight due to high proportions of lean muscle mass (Burkhauser et al 2009). An uninformed application of the body mass index to professional athletes, for example, would incorrectly conclude that the (admittedly selected) sample is unhealthily overweight. In the nineteenth century

[1] BMI is measured as the ratio of an inmate's weight (in kilograms) to height in meters squared or BMI = kilograms/meters^2

a high BMI value may have been associated more with lean muscle mass than body fat and, therefore, with greater productivity in physically demanding jobs. High BMI people had more attractive labor market prospects and were less likely to turn to crime. Second, even if body mass index values from the mid-nineteenth and early twentieth centuries are measuring the same thing, namely excess body fat, the relatively high and rising real cost of food in the mid-nineteenth century implies that individuals with relatively high BMI values were probably economically better off than those with lower BMI values and found entry into crime less attractive.

2. The Economics of Human Physiology and Crime

For nearly two centuries, social scientists have attempted to link crime and human physiology, an approach sometimes labeled biological positivism (Gottfredson and Hirschi 1990). Nineteenth century physiognomy and phrenology, which linked criminal propensities with either facial features or bumps on the skull, as well as Cesare Lombroso's early twentieth century atavism, or degenerative evolution, are now scientifically discredited (Vold and Bernard 1986; Curran and Renzetti 1994). But Lombroso's approach inspired Charles Goring's (1913) research in which he uncovered a correlation between a combination of short stature and low body weight and criminality. Although he rejected Lomroso's notion that there was a discernible physical criminal type, Goring's conclusions, too, are now largely discredited because he hypothesized that small physical size indicated an unobserved underlying genetic inferiority that led to criminality.

In the subsequent three decades Ernst Kretschmer (1925) and William Sheldon and associates (see particularly Sheldon, Hartl and McDermott 1949) offered theories based on broadly defined body types rather than specific measurements. Although the Kretschmer and Sheldon approaches differed in some respects, each divided individuals into three broad body types: athletic (mesomorphs), thin (ectomorphs) and fat (endomorphs). Both men contended that individuals with more athletic builds were more likely to engage in criminal activity, though neither developed a compelling explanation for the association.

No biological positivist approach has withstood sometimes withering criticism largely because, although grouped together as biological *positivism*, each offered a variant of biological *determinism*. Gottfredson and Hirschi (1990) and other modern criminologists reject the positivist approach, first, because there is no solid modern evidence linking crime with genetic predispositions and, second, because none of these approaches offered a theory of criminality that generated clearly articulated testable hypotheses. Without a theory, "positivism is reduced to endless examination of lists of possible physiological, anatomical, and constitutional variables that may or may not be correlated with behavior" (Gottfredson and Hirchi 1990, p.53). In modern statistical parlance, the failure to produce a guiding theory meant that researchers often confounded left-hand and right-hand side variables in a potential regression equation. And later studies that offered formal statistical tests provide "minimal" or "near zero" evidence that inherited or genetic factors (such a height or weight or body type) correlate with criminal activity (p.60).

That modern criminological theory rejects biological determinism does not mean that biology, particularly human physiology, has no bearing on criminal activity. Economists have recognized that heritable physical features, such as attractiveness, translate into differential labor market opportunities (Hammermesh and Biddle 1984). Once differential job prospects are linked with criminal propensities, as in Becker (1968), economics offers a theoretical link between human physiology and criminal activity. The economic approach (discussed in more detail below) posits the rational criminal who, when faced with an opportunity to engage in either legitimate or criminal behavior, will opt into criminality when the payoff to legitimate labor market activity is lower than the payoff to crime.

Mocan and Tekin (2006) offer the quintessential test of the link between attractiveness and criminality and find that people considered unattractive by disinterested observers commit more crime than average looking people. Moreover, attractive people commit less crime than average looking people. They argue that this association exists because attractiveness is rewarded in the legitimate labor market so that attractive people earn a wage premium. Criminal activity is less appealing because the opportunity cost of criminal activity is higher for attractive than for unattractive individuals.

There is also abundant empirical evidence that individuals outside the normal height and/or weight-for-height standards (often measured by the body mass index, hereafter BMI) suffer several premarket and market penalties. Persico, Postlewaite and Silverman (2005) and Case and Paxon (2008) uncover educational and wage penalties for shorter individuals. Not only are tall people believed to be more attractive than short people, they are believed to be more productive and thereby receive a wage premium. Although Mocan and Tekin (2006) argue that being overweight and being unattractive are not coincident, health and labor economists have uncovered a link between obesity and lower wages, as well as obesity and success in the marriage market, particularly for women (Averett and Koreman 1996; Cawley 2004; Cawley and Danziger 2005; Morris 2006; Han, Norton and Stearns 2009). Further, Averett and Korenman (1996) and Cawley (2004) find some evidence of an inverted U-shaped distribution of male wages or employment probabilities on weight. That is, underweight and obese men both pay a wage penalty. Han et al (2009) posit, but do not prove, that the observed wage penalty for underweight and overweight individuals follows from customer and employer distaste for individuals with extreme BMI values. Their conjecture reflects American prejudices against individuals with extreme BMI values, which appear to influence labor market outcomes.

If the economic theory of crime holds, people outside the normal BMI values, may have greater crime propensities than people in the normal weight-for-height range not because of any genetic predisposition among ectomorphs or endomorphs toward crime, but because poorer labor and/or marriage market outcomes lower the opportunity cost of crime. Two existing studies are broadly consistent with this prediction. Although Maddan et al. (2008) suggest that BMI is a poor predictor of criminality among Arkansas prisoners, BMI values are correlated with crime type. High BMI prisoners are less likely than normal BMI prisoners to have been imprisoned for violent acts. In a related study that used a sample of prisoners housed by the Mississippi Department of Corrections, Price (2009) finds a correlation between obesity and the age at which an individual transitions into criminal activity. Heavy people have greater probabilities of entering into criminal activity than people of normal weight. Thus, there is evidence connecting body type or BMI with criminality, an association readily explained by modern economic theory. This paper offers an historical investigation of the connection between the transition into crime and individual BMI values.

3. Theory and Methodology

We follow the approach of Kiefer (1988), Gyimah-Brempong and Price (2006), and Price (2009), and adopt a continuous-time approach to criminal activity. It is assumed that over their life-cycle, individuals are presented with opportunities for criminal activity, and engage in it if it is in their best interest. Individual transitions into crime are viewed as a hazard that consists of the product of two probabilities or $h(t) = \eta\pi$ where η is the probability that an individual faces an opportunity for criminal activity, and π is the probability that the opportunity for crime is acceptable.

To the extent that body weight is associated with wage penalties (Cawley, 2004; Morris, 2006) and/or constrains employment outcomes (Cawley and Danziger, 2004; Han, Norton, and Stearns 2009), the acceptability of criminal activity for individuals could be a function of their body weight. Suppose the probability that criminal activity is acceptable is given by $\pi = \int_{y^*(\phi)}^{\infty} f(y)dy$, where $f(y)$ is the probability of earning y from criminal activity, φ is a monotonic measure of an individual's weight, and $y^*(\phi)$ is an individual's reservation earnings from criminal activity defined as the minimum level of earnings from crime at which he or she would engage in criminal activity.

If body weight conditions labor market opportunities, then $\partial y^*(\phi)/\partial\phi \neq 0$. In general, the effect of body weight on the individual transition into crime is $\partial\pi/\partial\phi$ = $\partial\pi/\partial y^*(\phi)\times\partial y^*(\phi)/\partial\phi$. If body weight does not matter for labor market opportunities, then as $\partial y^*(\phi)/\partial\phi = 0$, $\partial\pi/\partial\phi = 0$, or body weight does not condition individual transitions into criminal activity. Otherwise, if body weight is associated with labor market disadvantages, then either $\partial y^*(\phi)/\partial\phi > 0$, and the individual crime hazard increases with respect to body weight, or $\partial y^*(\phi)/\partial\phi < 0$, and the individual crime hazard decreases with respect to body weight.

Our econometric approach to examining the effect of body weight on individual transitions into crime assumes that individual crime hazards in the 19th century were similar to those in the 20th century in that individual crime hazards are a monotone, perhaps decreasing function of time (Gottfredson and Hirschi 1990). We adopt a Weibull proportional hazard regression specification of the form h(t) = $h(o)exp(\sum_i\beta_k X_k)$, where $h(o) = pt^{p-1}exp(\beta_o)$, p is a shape parameter, t is time, and $exp(\beta_o)$ is the scale parameter.[2] For a given explanatory variable X_k, its effect on the individual transition into crime is given by β_k. Given that we observe an individual making a transition into criminal activity at time t, our econometric specification of individual crime hazards allows us to

[2] Let T be a non-negative random variable measuring the time to an event, the survivor function—the reverse cumulative distribution function of T—is $S(t) = 1 - F(T) - Pr(T > t)$, where $F(T) = Pr(T \leq t)$. If survival probabilities have a Weibull distribution, then $S(t) = exp(-\lambda t^p)$, where λ is a scale parameter, and p is a shape parameter. If we let $\lambda = exp(\beta_o)$, The unconditional hazard function is:

$$h(t) = [\partial S(t)/\partial t)]/S(t) = [exp(\beta_o)\, pt^{p-1} exp(-exp(\beta_o t^p)]/exp(-\lambda t^p) = exp(\beta_o) pt^{p-1}$$

conditioning h(t) on a vector explanatory variables $\sum_i\beta_k X_k$ results in a Wiebull proportional hazards regression model (Cleves, Gould, and Gutierrez, 2004):

$$h(t|\mathbf{X}) = [\partial S(t)/\partial t)]/S(t) = [exp(\beta_o)\, pt^{p-1} exp(-exp(\beta_o t^p)]/exp(-\lambda t^p) = exp(\beta_o + \sum_i\beta_k X_k\ ) pt^{p-1}$$

where **X** is a vector of explanatory variables determine the impact that body weight has on the probability of making a transition into criminal activity.

4. Data

To study the historical association between individual BMI values and the transition into crime, we make use of records generated at the Tennessee state penitentiary between 1831 and 1870 and the Illinois state penitentiary at Joliet between 1847 and 1892 (Sherrill and Sherrill 1997; Illinois Genealogy Trails 2006). Existing studies have used nineteenth-century prison records in studying racial or ethnic discrimination in sentencing and systematic racial or ethnic differences in prisoner BMI and well-being, but to our knowledge no previous study has used these records to understand factors influencing the transition into criminal activity (Bodenhorn 2009; Carson 2007; Carson 2009).

When a convicted felon was delivered to the penitentiary to serve his or her sentence, clerks recorded general and personal information in ledgers or registers. In the Tennessee records, for example, the clerk assigned each prisoner a number, recorded his or her name, the date he or she arrived, his or her crime (which ranged from petit larceny to first-degree murder), the court-assigned sentence the prisoner was expected to serve, and the county of conviction.[3] In addition, the clerks recorded the prisoner's age at intake, his or her pre-conviction occupation, nativity (US or foreign), race, marital status, as well as his or her height and weight. The Illinois records included all of this information and, in addition, recorded whether the prisoner was literate and whether he or

[3] Each prisoner's sex was inferred from given names: prisoners with names like James, William or Robert were considered to be men; those with names like Sarah, Ann or Mary were considered to be women. Only a handful of ambiguous or barely legible cases (Francis versus Frances) were excluded.

she was intemperate. Clerks did not report weights for every prisoner, but the Tennessee and Illinois records generate 1019 useable observations.

Table 1 reports the definition, mean and standard deviation of the covariates utilized to estimate the effects of body weight on individual crime hazards in the 19th century. Our measure of body weight is an inmate's Body Mass Index (BMI). We also consider the effects of being in distinct weight classes based on the BMI: Underweight (BMI<20), Normal Weight (20≥BMI>25), Overweight (25≥BMI>30), Obese (BMI≥30), and Heavy (BMI≥25), which combines the usual Overweight and Obese categories. As control variables we include binary measures of an inmate's sex, race and ethnicity. Our dependent variable is an age-specific hazard, and it measures the age at which the inmate entered prison at his or her most recent conviction. We do not know whether a particular inmate is serving time for his first conviction, or if he has committed crimes previously that either went undetected by law enforcement or were punished by a sentence served at a county jail. Our age at incarceration measures the age at which an individual entered the state penitentiary for a crime, but this may or may be the age at which he or she initially entered into criminal activity. Thus, our parameter estimates capture the effects of the explanatory variables on the individual transition into prison and not necessarily that individual's initial entry into criminal activity. That we cannot account for recidivism should not introduce a notable bias because, in his study of offending and sentencing in nineteenth-century Pennsylvania, Bodenhorn (2009) finds relatively few recidivists, though there were high recidivism rates among the few recidivists.

5. Results

Table 2 reports simple Wiebull proportional hazard parameter estimates—as hazard ratios—for the effects of 6 different measures of body weight on the individual transition into illegal activity. As diagnostic measures, Table 2 also reports a chi-square test for the significance of the overall regression, and a Wald Test for a constant (proportional) hazard.[4] The regressions are significant, and the Wald Tests for a constant hazard is rejected—suggesting that a Wiebull specification for individual crime hazards is adequate. With the exception of Underweight and Obese, the estimated hazard ratios are significant. Estimated hazard ratios on BMI, Overweight, and Heavy are less than one, which implies that individuals who were "fat" along these dimensions were less likely to transition into criminal activity.[5] In contrast, the hazard rate associated with Normal weight is greater than one and statistically significant, which implies that not being thin or heavy accelerated the age at which an individual made a transition into criminal activity. The last column reports estimate with three of our overlapping binary measures of obesity with normal weigh being the excluded body weight measures. The pattern of significance is generally consistent with the other estimates—being fat relative to a normal weight reduces the likelihood of an individual making a transition into criminal activity.

The parameter estimates in Table 2 identify a causal effect of body weight on individual crime hazards if there are no unobservables or individual heterogeneity that matter for our crime specification. Even if we interpret the hazard ratios as a partial or

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[4] In particular the Wald Test is for the hypothesis H_o: $ln(p) = 0$, which is equivalent to H_o: $p = 1$. Because a Weibull distribution assumes that individual hazards are monotonically increasing or decreasing over time, a rejection of the null hypothesis is an indication that a Weibull distribution is adequate for explaining the individual transitions into crime.

[5] We use the term "fat" reluctantly for reasons offered below.

marginal effect, all else equal, our estimates may not provide a true causal effect for two reasons. First, if there are important unobservable variables correlated with body weight that also condition entry into criminal activity, the simple Weibull parameter estimates may be biased upwards. Second, our sample consists of criminals who were arrested, tried, convicted and sentenced to the state penitentiary and, as such, might represent a selected, non-random sample. Because we do not observe criminals who did not reach the end of the criminal justice procedure, the parameter estimates reported in Table 2 might be subject to sample selection bias.

We control for possible biases in the parameter estimates in Table 2 by estimating the Weibull hazard specification with unobserved frailty—defined as an unobservable and random risk factor measuring unobservable individual predisposition toward crime that modifies the crime hazard function of individuals.[6] Viewed as a random effect, introducing individual frailty into a Weibull proportional hazard specification identifies causal effects because it is assumed that the individual frailties are uncorrelated with the explanatory variables. If individual frailty also accounts for the unobserved and unmeasured covariates that are potentially important determinants of success in criminal activity, parameter estimates of a Weibull individual crime hazard specification with individual frailty will also mitigate any sample selection bias.

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[6] For an overview of proportional hazard models with unobserved frailty , see Cleves, Gould and Guitierrez (2004, Chapter 9), and Wienke (2003). For specific applications of proportional hazard models with unobserved frailty see Price (2008) and Price, Darity, and Headen (2008) In general, a Weibull proportional hazard specification with individual frailty is:

$$h(t|\,\boldsymbol{X}) = \alpha_i\, h(t|\,\boldsymbol{X}) \;=\; \alpha_i\, exp(\beta_o + \textstyle\sum_i \beta_k X_k\;)pt^{p-1}$$

where α_i is the frailty individual *i*—some unobserved individual specific effect—assumed to have a mean of unity, and a variance of $\theta > 0$.

Table 3 reports Wiebull proportional hazard parameter estimates with individual frailty—again as hazard ratios—for our six measures of body weight on the individual transition into criminal activity. The distribution of the frailty is assumed to be inverse Gaussian.[7] Table 3 also includes a diagnostic chi-square distributed test for a zero frailty variance—which is rejected.[8] The overall regressions, corrected for frailty, are significant, and the Wald Tests for a constant hazard are rejected, which again suggests that a Wiebull specification for individual crime hazards is appropriate.

Even after controlling for unobserved heterogeneity—omitted variables that may matter for individual transitions into criminal activity, and may be correlated with getting caught and incarcerated—the results are nearly the same as those reported in Table 2. The individual crime hazard is decreasing in BMI, and lower for individuals classified as Overweight and Heavy. The magnitude on Normal weight remains significant and greater than unity, again suggesting that not being "fat" made an individual more likely to make a transition into criminal activity. These results accord with findings dating back to Kretschmer (1925) and Sheldon et al (1949) that those with athletic frames were more likely to engage in criminal activity. It is also consistent with Maddan et al.'s (2008) findings that mesomorphs are more likely to engage in violent, as opposed to nonviolent, felonies. Finally, as was the case for the parameter estimates in Table 2 being fat relative to a normal weight reduces the likelihood of an individual making a transition into criminal activity.

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[7] Estimating the parameters of a Wiebull proportional hazard model with individual frailty requires imposing a mathematically tractable distribution function for the unobserved frailty. Two distributiona1 choices are available in *STATA*: 1) Gamma distribution and 2) Inverse Gaussian distribution. None of our specifications achieved convergence when the Gamma distribution was selected.

[8] Given individual unobserved frailty with mean of unity and variance of θ, rejecting H_o: $\theta = 0$, implies that unobserved heterogeneity in the population conditions the crime hazard.

Our parameter estimates are interpretable within a theoretical framework that allows legitimate opportunities, such as employment in the labor market to be conditioned on an individual's body weight. As such, the parameter estimates in Tables 2 and 3 suggest that in the 19th century, successful employment outcomes were positively related to an individual's body weight. Such a finding runs counter to the one existing estimate of the effects of weight on crime hazards in the 20th century. Price (2008) finds that increases in individual body weight increase the likelihood of criminal activity. His finding is consistent with fat or obese individuals facing labor market disadvantages with respect to employment and/or wages, which lowers the return to legitimate labor market activities relative to illegitimate criminal activities, and thereby increases individual crime hazards. To the extent that being fat is a component of beauty that employers do not value, our results also seemingly run counter to that of Mocan and Tekin (2006), who find that criminals are physically less attractive than non-criminals. Our results are, however, consistent with Madden et al (2008) who find that high BMI individuals (endomorphs) are less likely to have participated in violent crime.

We suspect that our parameter estimates measure a different labor market consequence of weight, which we are reluctant to label "fatness" (at least for the Overweight group) in the 19th century. We believe that in the 19th century, there was a complementarity between body weight and jobs on average, given the physical exertion or "brawn" required of many jobs, such as farming, construction, and common labor, in an age before mass mechanization.[9] Komlos (1984) estimated that US aggregate food

[9] There is evidence of a complementarity between body weight and job type. Both Everett (1990) and Puhl and Brownell (2001) found that employers perceived the suitability of employees for jobs that required face-to-face contact to be a function of their body weight, with obese individuals viewed as less suitable for such jobs.

production in 1849 was consistent with a caloric intake of about 3,400 calories per adult male day. This caloric intake represents more than enough fuel to support normal (modern) work effort, but it was barely sufficient, at best, for the physical exertion demanded of many 19th century occupations. We know, for example, that slaves on southern plantations regularly consumed as much as 4000 to 5000 calories per day to provide the fuel necessary to put in the work demanded of them (Fogel and Engerman 1974).[10] Although free labor was probably not driven at the same grueling pace as plantation slaves, Komlos's (1984, p.912) study of West Point cadets found that most were underweight. Their low weights indicate "that the claims on their caloric intake must have been enormous."

What makes Komlos's result all the more compelling is that West Point cadets were, by and large, from relatively well-off families. Imagine the caloric intake necessary to fuel a day working a team of horses, or felling trees or digging a canal, as well as the lean muscle mass necessary to engage in this labor for many hours a day for months at a time required of less well-off individuals. Regular employment in heavy, nonmechanized labor was likely to result in 19th-century workers with much more lean muscle mass than follows from most 20th-century employments. Because lean muscle mass is denser than body fat, it is important to recognize that BMI values in excess of 25 may not be measuring the same physical characteristics then as now (Bodenhorn 2009 makes a similar argument). We might then think of "Overweight" individuals more akin to modern athletes, whose regularly report BMI levels well in excess of the normal range of

[10] We are unaware of any data set containing both slave heights and weights (height data alone are abundant), so we cannot calculate slave BMI. Extant photos of slaves, most of which were taken shortly after emancipation, reveal thin, very muscular frames, which is consistent with elevated weight-for-height or higher BMI values than would be considered normal today.

20 to 25 and yet who are in incredible physical condition. Saint Onge et al (2008), for example, find historical BMI values of American Major League baseball players to have been greater than the general population.

We contend that our hazard model results are consistent with "relatively underweight" (what might now be considered normal weight) people exhibiting a greater propensity toward criminal activity than relatively normal individuals because their relatively low weight made them appear unproductive to prospective employers. Many 19th century occupations required "brawn" and those workers who appeared well fed, and sporting lots of lean muscle mass earned a wage premium, which allowed them to continue to purchase the nutrients needed to sustain their productivity advantage.

Not only did physical requirements of daily work effort alter people's body types, economic factors were at work as well. Komlos (1984) documented that per capita food production actually declined in the 1840s and it did not recover its 1840 level again until 1880. The ratio of wages to food prices also peaked in the 1820s and it is possible that declines in the prices of manufactured goods relative to food prices further encouraged substitution out of food consumption and into other products. Both the rising real prices of food and its increasing relative price would have encouraged diminished food consumption. The result of which was declining adult stature and low weight-for-height measures.

In addition, Bodenhorn's (2009) study of the BMI values of mid-nineteenth century New York legislators reveals that these relatively economically privileged individuals were heavy , with an average BMI values of approximately 24, compared to the general US male population average of about 22.5 in the early twentieth century

(Fogel 1994). Thus, unlike modern Americans for whom BMI values tend to be inversely related to income or economic status, nineteenth-century Americans demonstrated a positive relationship. It is not surprising then that individuals in the Overweight category were less likely to enter into crime. They likely faced better labor market opportunities.

The sorts of job-related nutrition and caloric demands in the nineteenth century stand in stark contrast to modern times in which sedentary service jobs, which presumably require little "brawn," account for much modern employment. For example Li, Wang, and Zhai (2003) show that in 1890 the service sector accounted for just over 10 percent of total U.S. employment, whereas in 1998 it was approximately 60 percent. The historic contrast between the late 19th and 20th century in the employment share of the service sector suggests that the physical brawn requirements of jobs over time were different. Given different perceived or actual physical brawn requirements, and if employers at least have a discriminatory preference for different body weights in employees, a possible mismatch between individuals and jobs emerges—a mismatch that can possibly create labor market disadvantages that impact upon individual crime hazards.

We can test this hypothesis because our data report for each inmate in the sample, a broad job description of each inmate's job held prior to conviction. We exploit this information to examine how body weight conditioned the probability of being employed in jobs that required in our view, physical brawn in the 19th century. Each inmate was assigned one of the follow occupational classifications: Clerical, Craftsman, Farmer, Laborer, Operative, Professional, Proprietor, Sales, Service, and No Occupation. We created two categories of job-types: one that in our view required significant brawn in the

19th century and one that did not. An inmate's job category required significant brawn if he reported his occupation as Craftsman, Farmer, Laborer, Operative, and No Occupation. A binary value of one was assigned to an inmate if he was employed prior to prison entry, in a job that required significant brawn.[11]

Table 4 reports population-averaged Logit fixed effect parameters estimates on the effects of body weight on our binary measure of an inmate being employed in a job that required significant brawn prior to prison.[12] Diagnostically, the regression is significant overall for all specifications. Similar to the crime hazard parameter estimates in Tables 2 and 3, for all but two measures of body weight—Underweight and Obese—the estimated parameters are significant. The signs on BMI, Overweight, and Heavy are positive, suggesting that being fat along these dimensions increased the probability of being employed in a job that required brawn. In contrast, the sign on Normal Weight is negative, suggesting that being relatively "less fat" along this dimension decreased the probability of being employed in a job that required brawn.

The pattern of sign and significance for the parameter estimates in Table 4 suggests that the mechanism by which being relatively "less fat" mattered for crime is that in the 19th century, many jobs probably required brawn. This suggests that there was a complementarity between a "fat" body weight and jobs. If BMI represents a measure of

[11] In our sample, approximately 90 percent of the inmates held employment prior to prison entry in our measure of "brawny" jobs.

[12] We implement a fixed effects estimator to control for observed heterogeneity and omitted variables that could lead to biased parameter estimates. Our choice of a population-averaged Logit estimator was driven by convergence considerations—we could not obtain it with a simple Logit fixed effect estimator. A population-averaged Logit estimator implements the fixed effect by parameterizing it through panel-level covariance, instead of subject-level covariance from the standard fixed effect estimator (Hardin and Hilbe, 2003). The fixed effect is based on inmate literacy groupings—a variable that indicates whether or not the inmate is literate. This assumes that any unobserved heterogeneity associated with the type of job held prior to prison entry is correlated with whether or not the inmate is literate—which is correlated with individual general and specific human capital.

the ratio of nutrition to work effort, as Carson (2009) contends, low-BMI individuals could be mismatched to a job that required high expenditures of physical energy. Thus, in the 19th century, if an individual had a relatively low BMI, he likely faced disadvantages in the labor market which increased the probability of transitioning into crime.

6. Conclusions

We consider the extent to which crime in the 19th century was conditioned on body weight. Parameter estimates from Wiebull proportional hazard specifications reveal that consistent with a theory in which body weight can be a source of labor market disadvantage, crime in the 19th century does appear to have been conditioned on body weight. However, in contrast to the 20th century, in which labor market disadvantage increases with respect to body weight, our results suggest that in the 19th century, labor market disadvantage decreased with respect to body weight, causing individual crime hazards to decrease with respect to body weight. In our view, this is consistent with a 19th century complementarity between body weight and typical jobs that required adequate nutrition and caloric intake to support normal work effort and performance

Our parameter estimates are identified if the assumption that all individual heterogeneity is an unobserved frailty—a predisposition toward criminal activity—with a known mean and variance. As our parameter estimates of the individual crime hazard support this assumption, our results suggest that being relatively "less fat" in the 19th century, had a causal effect on individual criminal behavior. Nonetheless, a causal interpretation could be compromised by prisoners gaining weight in prison, causing our body weight measures to be endogenous as a result of reverse causality. As our dependent variable is age at prison entry, if inmate weight was measured at the date of prison entry, which we believe it was, then our inmate body weight measures, and parameter estimates of their effect on individual crime hazards are not biased.

Table 1
Covariate Summary

Variable	Definition	Number of Observations	Mean	Standard Deviation
Age	Age (in years) of inmate at prison entry	1017	28.96	10.10
BMI	Body Mass Index of inmate	1019	23.35	2.41
Underweight	Binary variable equal to 1 if for inmate: BMI ≤ 18.5	1019	.004	.062
Normal Weight	Binary variable equal to 1 if for inmate: 18.5 < BMI ≤ 24.9	1019	.768	.422
Overweight	Binary variable equal to 1 if for inmate: 24.9 < BMI ≤ 29.9	1019	.216	.412
Obese	Binary variable equal to 1 if for inmate: BMI > 29.9	1019	.012	.108
Heavy	Binary Variable equal to 1 if for inmate: BMI > 24.9	1019	.228	.419
Female	Binary variable equal to 1 if inmate is a female	1019	.007	.083
Black	Binary variable equal to 1 if inmate is a female	1019	.046	.209
Mulatto	Binary variable equal to 1 if inmate is a Mulatto	1019	.015	.120
Irish	Binary variable equal to 1 if inmate is Irish	1019	.023	.152
German	Binary variable equal to 1 if inmate is German	1019	.040	.197
Other Immigrant	Binary variable equal to 1 if inmate reports ethnicity/ancestry other than Irish or German	1019	.055	.228

Table 2
Weibull Proportional Hazard Parameter Estimates:
The Effects of Body Weight on Individual Crime Hazards

Specification: Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
BMI	.975						
	(.012)[b]						
Underweight		1.42					1.37
		(.715)					(.687)
Normal weight			1.19				
			(.090)[b]				
Overweight				.852			.844
				(.066)[b]			(.065)[b]
Obese					.641		612
					(.187)		(.179)[c]
Heavy						.827	
						(.063)[b]	
Female	.971	.914	1.01	1.01	.907	1.02	1.01
	(.369)	(.347)	(.388)	(.394)	(.344)	(.389)	(.384)
Black	1.17	1.13	1.15	1.14	1.15	1.15	1.17
	(.177)	(.169)	(.173)	(.171)	(.173)	(.173)	(.177)
Mulatto	1.36	1.37	1.36	1.36	1.36	1.36	1.36
	(.353)	(.356)	(.354)	(.355)	(.355)	(.354)	(.354)
Irish	.610	.589	.615	.605	.605	.617	.626
	(.127)[b]	(.122)[b]	(.128)[b]	(.126)[b]	(.126)[b]	(.128)[b]	(.130)[b]
German	.860	.842	.862	.853	.837	.843	.851
	(.138)	(.134)	(.136)	.137)	(.133)	(.136)	(.136)
Other Immigrant	.762	.749	.765	.760	.755	.766	.771
	(.105)[b]	(.103)[b]	(.105)[b]	(.104)[b]	(.104)[b]	(.106)[b]	(.106)[c]
N	1017	1017	1017	1017	1017	1017	1017
X^2_7: H_O: $\sum_i \beta_k X_k = 0$	19.41[a]	15.6[a]	21.13[a]	19.60[a]	17.83[b]	21.62[a]	23.24[a]
H_o: $ln(p) = 0$	48.32[a]	48.24[a]	48.42[a]	48.37[a]	48.32[a]	48.44[a]	48.47[a]

Notes:
Standard errors (in parentheses) are for the unexponentiated coefficients, whereas the coefficients are reported as hazard ratios.
[a]Statistically significant at the .01 level
[b]Statistically significant at the .10 level
[c]Statistically significant at the ..05 level

Table 3
Weibull Proportional Hazard Parameter Estimates with Individual Frailty: The Effects of Body Weight on Individual Crime Hazards

Specification: Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
BMI	.937						
	(.018)[a]						
Underweight		1.49					1.37
		(1.19)					(1.09)
Normal weight			1.45				
			(.168)[a]				
Overweight				.707			.698
				(.084)[a]			(.083)[a]
Obese					.521		.477
					(.236)		(.215)[c]
Heavy						.683	
						(.079)[a]	
Female	1.15	1.02	1.19	1.18	1.01	1.19	1.18
	(.657)	(.579)	(.679)	(.677)	(.574)	(.684)	(.675)
Black	1.12	1.03	1.08	1.06	1.06	1.09	1.10
	(.264)	(.243)	(.255)	(.249)	(.251)	(.256)	(.259)
Mulatto	1.49	1.51	1.53	1.53	1.49	1.52	1.52
	(.599)	(.613)	(.614)	(.617)	(.607)	(.615)	(.613)
Irish	.448	.415	.449	.438	.428	.449	.456
	(.143)[b]	(.133)[a]	(.143)[b]	(.140)[a]	(.138)[a]	(.144)[b]	(.147)[b]
German	.742	.702	.723	,725	.696	.724	.721
	(.185)	(.176)	(.179)	(.181)	(.174)	(.180)	(.179)
Other Immigrant	.639	.612	.638	.634	.616	.640	.643
	(.136)[b]	(.131)[b]	(.136)[b]	(.135)[b]	(.132)[b]	(.136)[b]	(.136)[b]
N	1017	1017	1017	1017	1017	1017	1017
X^2_7: H_O: $\sum_i \beta_k X_k = 0$	26.98[a]	16.44[a]	26.50[a]	24.82[a]	18.43[a]	27.06[a]	27.93[a]
H_o: $ln(p) = 0$	43.19[a]	42.85[a]	43.14[a]	43.15[a]	42.80[a]	43.15[a]	43.09[a]
H_o: $\theta = 0$	174.08[a]	167.33[a]	171.87[a]	171.71[a]	167.10[a]	171.93[a]	171.19[a]

Notes:
Standard errors (in parentheses) are for the unexponentiated coefficients, whereas the coefficients are reported as hazard ratios.
[a]Statistically significant at the .01 level
[b]Statistically significant at the .10 level
[c]Statistically significant at the .05 level

Table 4
Population-Averaged Fixed Effect Logit Parameter Estimates:
The Effects of Body Weight on Employment Type

Specification: Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Constant	-3.04	2.03	2.79	2.04	2.12	2.07
	(1.34)b	(.364)[a]	(.493)[a]	(.362)[a]	(.368)a	(.363)[a]
BMI	.234					
	(.059)a					
Underweight		6.61				
		(59.01)				
Normal weight			-.716			
			(.314)[b]			
Overweight				.551		
				(.310)[b]		
Obese					8.69	
					(39.15)	
Heavy						.704
						(.314)[b]
Female	-.915	-.519	-.718	-.683	-.489	-.716
	(.983)	(.915)	(.948)	(.939)	(.922)	(.947)
Age	-.028	-.019	-.024	-.022	-.022	-.024
	(.013)b	(.013)	(.013)[b]	(.012)[c]	(.013)[c]	(.103)[c]
Black	-1.97	-1.67	-1.80	-1.75	-1.79	-1.80
	(.377)a	(.351)[a]	(.362)[a]	(.357)[a]	(.363)[a]	(.362)[a]
Mulatto	-2.11	-1.88	-2.10	-2.05	-1.89	-2.09
	(.806)b	(.779)[b]	(.799)[a]	(.793)[b]	(.780)[a]	(.799)[a]
Irish	.188	.304	.249	.249	.334	.249
	(.793)	(.788)	(.786)	(.786)	(.790)	(.786)
German	-.089	.070	.014	.015	.086	.012
	(.449)	(.441)	(.445)	(.444)	(.442)	(.445)
Other Immigrant	.292	.361	.320	.339	.288	.319
	(.448)	(.439)	(.441)	(.443)	(.437)	(.441)
N^d	477	477	477	477	477	477
X^2_7: H_O: $\sum_i \beta_k X_k = 0$	43.68[a]	31.93[a]	35.51[a]	34.14[a]	34.05[a]	35.38[a]

Notes:
Standard errors are in parentheses
[a]Statistically significant at the .01 level
[b]Statistically significant at the .10 level
[c]Statistically significant at the ..05 level
[d] Observations are dropped if they are unique to only one literacy grouping so as to permit appropriate fixed-effect averaging within a group.

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