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THE DECLINE IN THE NUTRITIONAL STATUS OF THE U.S. ANTEBELLUM POPULATION AT THE ONSET OF MODERN ECONOMIC GROWTH

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ABSTRACT

The decline in the physical stature of the American population for more than a generation beginning with the birth cohorts of the early 1830s was brought about by a diminution in nutritional intake in spite of robust growth in average incomes. This occurred at the onset of modern economic growth on account of rising inequality and an increase in food prices, which brought about dietary changes through the substitution away from edibles toward non-edibles. In a recent working paper, Bodenhorn, Guinnane, and Mroz question this consensus view, suggesting that a decline in heights in a military sample may not be representative of the population at large. They argue that increasing wages in the civilian labor market may well induce an increased proportion of shorter men to volunteer for military service thereby driving down the mean height of soldiers even if the height of the population remains unchanged. However, they neglected to examine whether labor market conditions did actually improve during the Civil War in such a way as to induce shorter men to enlist. Had they done so they would have found just the opposite: during the course of the war real compensation in the military increased by some 39% to 66% relative to civilian earnings. This should have led to an increase in military heights if the logic of their model were accurate, when in fact they declined. Both the historical evidence and an assessment of the model indicate that failing to consider patriotism as a powerful motive for enlisting was another serious error. A thorough analysis of the Union Army height data, considering recruiting periods as short as 90 days during which labor market conditions could not have changed markedly indicates that there can be no doubt at all that the decline in the height of soldiers beginning with the birth cohorts of the early 1830s is representative of the trend in the physical stature of the male population at large. The implication is that there was a widespread diminution in nutritional status of the population in the antebellum period.

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1. The antebellum puzzle and the critics

The “Antebellum Puzzle” refers to the finding, first reported no less than thirty six years ago, that the physical stature of the male U.S. population,—although the tallest in the world at the time,—declined during the decades preceding the Civil War (Fogel et al. 1979). The finding, based on the height of soldiers in the Union Army (Margo and Steckel, 1983), was considered quite an anomaly at first on account of the fact that according to conventional thinking physical stature—a measure of nutritional status—was not expected to decline in a dynamic economy in which average incomes were increasing. After all, physical stature of a population is generally an increasing function of income; so *ceteris paribus* it should not decline during prosperous times. In reflecting upon this finding decades later, Richard Steckel, among the earliest contributors to this literature, wrote that the shrinking of the population in a growing economy “challenged firm beliefs that the quality of life was improving unambiguously after 1830….” (Steckel 1998, p. 808).

Thus, for those academics whose mental models focused exclusively on one-dimensional economic agents it seemed challenging to accept the implications of multidimensional conceptualizations of living standards and to entertain the notion that monetary measures failed utterly to capture several key aspects of biological well-being. Or, to put it another way, it appeared inconceivable to many at the time that the trend in some welfare indicators were diverging from one another. The reason is that the Whiggish interpretation of economic history insists that the effects of economic growth must be positive in all aspects of human experience. Thus, to acknowledge that economic growth brought with it not only advantages but, for at least one or two generations, interfered with the biological growth processes of children and youth would have contradicted this reading of the past.[1] Hence, in defence of this preconceived notion they had a tendency to introduce into the discussion “Ptolemaic epicycles” similarly to how the defenders of the geocentric view of the solar system introduced such modifications in order to defend their paradigm

[1] Lee Craig put it this way: “The ‘optimists’ viewed modern economic growth and its boon companion, industrialization, as unambiguously good -- led as they were by good things like the market…. But before they [the optimists] could secure final victory, there emerged a research agenda that yielded a new set of weapons…. Rather than GDP per capita, the Hectors of this war hurled biological indicators like mortality rates, stature, and body-mass indices… the ‘antebellum puzzle,’... breathed new life into the pessimists’ case” (2005).

from the Copernican model of the universe. This is a rather predictable impulse as Kuhn explained ages ago (1962).

It took almost four decades of intense research to establish a consensus view according to which physical stature declined in the U.S. at the onset of modern economic growth for a couple of generations beginning with the birth cohorts of the early 1830s because of the diminution in nutritional intake of the population in spite of the fact that average incomes were growing at the time (Craig 2016). From a theoretical perspective, we know that height is a positive function of income; in fact, in every single data set examined so far we find—without exception—that wealthier parents *everywhere* and *always* had and have taller children, everything else being equal. As amazing as it sounds, there is absolutely no exception to this generalization as long as there are no simultaneous offsetting forces at work. Thus, we infer that there must have been some offsetting effects which counteracted the salutary increases in average income during the antebellum period. These offsetting effects were not difficult to discern: they included a rise in inequality and a steep rise in food prices both absolutely and relative to manufactured products and the dietary changes they brought about through the substitution away from edibles toward non-edibles.

Now come Bodenhorn, Guinnane, and Mroz (2015) as the most recent sceptics with a classic Ptolemaic effort to question the consensus view by arguing that the declining trend in physical stature in the antebellum U.S. is based on incorrect inferences. They "doubt the evidence adduced for this apparent decline," (2015, p. 3) and argue that the decline in height was actually due to a biased selection process into the military. They suggest that the propensity of recruits to enter the military depended on labor market conditions: "As the economy grew, the outside option of military service became less attractive, especially to the productive and the tall. Military heights declined because tall people disproportionately chose non-military employment. Thus, we cannot really say whether population heights declined." (Underline in the original; Bodenhorn, Guinnane, and Mroz, p. 4). To put it simply, they claim that the decline in the height of soldiers is merely the consequence of a biased sample. It is the outcome of negative selection into the military: shorter men entered the military over time as the economy improved so that the soldiers are not a representative sample of the population of all men in the society. Thus, they claim that height of soldiers declined but that of the population may not have.

The theoretical basis of their argument is a model in which height is rewarded with higher incomes in both military and civilian life, but differentially so. When the civilian labor market pays more for height than does the army, shorter-than-average men tended to enlist and military heights understate the population mean. If the differential civilian return to height increases during an economic boom, negative selection on height is more pronounced, leading to a diminution in military height that is entirely unrepresentative of population trends.

While it is, of course, theoretically possible that general labor market conditions could have affected the supply of recruits and therefore the mean height of soldiers, it is disappointing that Bodenhorn, Guinnane, and Mroz actually presented no empirical evidence whatsoever to bear on the course of wages in the private sector or in the military during the Civil War. The extant evidence, however, blatantly contradicts their supposition. The fact of the matter is that real wages in the civilian sector declined relative to military pay by some 39% to 66% during the course of the war as demonstrated in Appendix B.[2] Hence, on account of pecuniary considerations, i.e., if wage differentials had made a difference at all to recruitment decisions then the military should have been more attractive to taller men over time and the height of the soldiers should have increased, assuming that height was a positive function of wages. Hence, the effect of selection would have been exactly the opposite of what they suppose it was. In fact, military heights declined while relative military pay increased refuting their hypothesis straightaway.[3]

We show below that their contention is way off the mark: the decline in physical stature in the antebellum U.S. is on such an extensive evidential basis that there cannot be any doubt that the decline in height reflects the actual nutritional experiences of the population who lived through that historic epoch of economic transformation and not only those who entered the military.

We next provide evidence on recruiting practices and model the process in order to demonstrate that the antebellum puzzle pertains to population heights and not only to military ones. Section 3 includes a new thorough analysis of the trend in the height of the

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[2] Real wages in the North declined continuously during the course of the war: compared to 1860 they declined by 4%, 13%, 16%, 26%, and by 1865 the decline was no less than 28% (Carter, et al., 2006, Tables 8a4280-4282 and Table CC1-2). In New England real wages declined by 35% (Carter et al, 2006, Table Ba 4271-4279). DeCanio and Mokyr estimate the cumulative loss of a worker's income between 1860 and 1865 as $317, i.e., the loss in income in each of the war years combined. This was about the annual income in 1862 (in 1860s prices) (1977, p. 324).

[3] Besides, only 30% of the labor force worked for a wage in 1850, i.e., most of the workers were self-employed and not directly affected by movements in wages (Lebergott, 1964, p. 139).

Union Army soldiers. Section 4 recounts the extensive evidence on which the current consensus is based; thereafter we refer to the recent work of Ariel Zimran who recently reaffirmed the existence of the Antebellum Puzzle and point out a number of further mistakes in Bodenhorn, Guinnane, and Mroz's arguments. We conclude by suggesting that their allegations are nothing more than a tempest in a teapot: that the mean height of the U.S. population declined at the onset of modern economic growth is incontrovertible.

2. Modelling Union Army recruitment

2.1 *Military history*

The most influential evidence of the antebellum puzzle comes from the Civil War data first analysed by Fogel et al. (1979). In order to understand the possible role of selection effects we need to examine the institutions surrounding recruitment into the Union Army. Huge numbers of northern men served in the Civil War; by some estimates more than 40% of the native-born, adult, white male population were at some point involved in the conflict. Here we review the basic features of the recruitment process, which changed dramatically over the course of the war.

In the first year of the war (April 1861 – June 1862), recruitment was strictly on a volunteer basis and strictly state-based. It was very successful. Indeed, the flow of new recruits at times exceeded the army's ability to train, equip, and deploy them, and total numbers exceeded the Federal government's summer 1861 call for 300,000 men. In April 1862, recruiting was actually suspended briefly. Alongside the enthusiasm for adventure and glory among young men that often accompanies an outbreak of war, local community pride and patriotism played a major role in motivating volunteers. In their letters, soldiers often refer to their commitment to the cause of preserving the Union and, in some cases, abolishing slavery. What do not appear to have played a role in the decision to volunteer, or at least not to have played a *positive* role, are economic considerations. The army paid privates just $13 per month, at a time when the wage for unskilled labour was roughly a dollar per day. Even a Federal enlistment bounty of $100 (payable on discharge) failed to make this competitive with civilian incomes – even without considering the relative risks of death or crippling injury in the two sectors. Military compensation was about 64% of urban wages as shown in Appendix B even if one adds the value of rations to soldiers' pay. Volunteers knowingly made a sacrifice, often imposing hardships on dependents they left behind.

Recruitment patterns began to change over the next eight months or so (July 1862 – February 1863). By the summer of 1862 it was clear that the war would not be short and glorious, and the reality of army life became well known: not just the carnage of battle but also pervasive illness in camps; poor food and miserable living conditions; lack of furloughs; an absence of prisoner exchanges; and pay not only low but late and irregular. The Militia Act of July 1862 empowered the President to call up state militias for Federal service for nine months, specified that states which failed to attract the requisite number of men through voluntary enlistment were to make up the difference through a draft, and directed states to establish regular conscription procedures toward this end. The Federal enlistment bounty began to be paid (at least partially) in advance, and was occasionally supplemented by local bounties offered by communities hoping to avoid being subject to a state draft.

A third period (March 1863 –June 1864) began with passage of the Enrollment Act in response to military setbacks that both sapped morale and made clear the need for more manpower. The Act established for the first time Federal conscription. Federal officials would now register all white male citizens aged 20-45, as well as immigrants who had declared an intention to become citizens.[4] Federal recruitment quotas were distributed across states, districts, and subdistricts, and when a subdistrict failed to fill its quota with volunteers, a draft was undertaken to fill the gap. Drafted men could furnish a substitute in lieu of serving personally, or could avoid all obligations by paying a $300 commutation fee. 18 and 19 year olds were a natural reservoir for such substitutes, as the minimum age for army service was 18, while conscription applied to men 20 and older. Importantly, there was no residence requirement for enlistment. Anyone enlisting in a community, any substitute provided for a drafted man, counted towards its quota. This resulted in competitive bidding for volunteers in the form of rising local enlistment bounties, and a brokerage business emerged to match men willing to fight (or at least enlist) with individuals and communities seeking substitutes. While monthly pay was not increased, the Federal enlistment bounty was tripled to $300 (even more for re-enlisting veterans) in October 1863. In the aftermath of New York’s infamous draft riots in the summer of 1863, the city began paying $300 to drafted citizens to permit them to pay commutation or furnish substitutes. While the new system was successful in eliciting a continuing flow of volunteers, and relatively little recourse was had to the draft, complaints about “bounty jumping” (collection of enlistment bounties by repeatedly signing up under different names in different localities), desertion, and the quality of recruits began to appear in this period.

[4] Voting was construed as such a declaration.

The final period we can distinguish (June 1864 – May 1865) began with the repeal of commutation, which had kept a lid on the price of substitutes and similarly kept a brake on local enlistment bounties. There is no systematic evidence on local bounties, but there are many examples that give an impression of their magnitude. In his study of Ohio, Murdock (1963) reports bounties rising from $85-100 in the spring of 1864 to much higher figures: $400 in Kenton (October '64), $550 in New Lisbon (March '65), and in some subdistricts $600-800 by the end of the war. In New York City, the price of a substitute in January 1865 was $1800 for a three-year man. More systematically, a February 1865 New York state law automatically gave $500 to drafted citizens who purchased a three-year substitute. These local bounties were a major burden on communities, which could no longer fund them through voluntary contributions and were forced to issue bonds and/or increase taxes significantly. Complaints about the quality of recruits grew louder. Murdock (1963, p. 6) writes that "Many of the substitutes or volunteers of the later war period were common criminals, waiting to desert at the first opportunity, who had to be shipped to the front in irons. It is little wonder that Grant, Sherman, and others protested at the human refuse dumped into their camps."[5]

2.2 *The model and the facts*

In their empirical work Bodenhorn, Guinnane, and Mroz explore how two patterns of selection on height could produce a spurious time trend: varying intensity of selection by age and by enlistment year. However, varying selection by age can be dismissed immediately for two reasons. First, there is no evidence in the historical record that contemporaries perceived a difference in the quality of recruits of different ages. Second, the logic of their model suggests that if a spurious trend were generated, it would be a *rising*, not a declining trend. We would expect a thirty-year old to have considerably higher opportunity costs of military service than an eighteen-year old: his civilian skills will be much more fully developed and better matched to his employment; he is more likely to have acquired a farm or business that requires his attention; and he is much more likely to have dependents. Among older men, then, it is disproportionately low-skilled, less-

[5] In the Union Army dataset the shares of draftees and substitutes among native-born soldiers jump from 0.7 and 0.6% before the Enrollment Act (presumably representing state conscripts) to 10.1 and 8.8% afterwards. Other observable contrasts that may be associated with social status include increases in the share of foreign-born recruits (from 27 to 33%) and, among natives, in illiteracy (5.4 to 6.7%) and the share of low-skilled occupations (15 to 19%). On the other hand, the share of native-born soldiers subjected to military discipline, e.g. for desertion, declined (from 20 to 13%), probably due to the significantly longer duration of service for early enlisters.

successful individuals who will volunteer, and they will tend to be shorter than average. Among young men, any such effect should be much weaker, so that average-height men volunteer. In a military sample, then, we should observe unrepresentatively short older men and average-size younger men, generating a spurious upward time trend in mean height. However, the antebellum puzzle is a downward trend thereby contradicting Bodenhorn, Guinnane, and Mroz's prediction.

If differential selection on height by age can be dismissed, the same is not true for enlistment year. Our review of recruitment practices indicates that there were substantial changes during the war which could well have induced different classes of men to enlist, thereby bringing about a negative selection on height. But the prediction of Bodenhorn, Guinnane, and Mroz's model is completely inconsistent with what actually happened. The model predicts that military heights will decline as relative military pay falls. In the Civil War just the opposite happened, army heights declined while army pay *increased* relative to civilian pay by between 39% and 66% (Appendix B).

Yet, it is not necessary to abandon Bodenhorn, Guinnane, and Mroz's model altogether. We can accommodate the salient features of Civil War experience by re-introducing patriotism into the model, in the form of Bodenhorn, Guinnane, and Mroz's relative preference for civilian life – "τ" in their notation. Bodenhorn, Guinnane, and Mroz assume $\tau = 0$ in their simulations. τ introduces additional noise into the model, attenuating the link between stature and willingness to volunteer. For the model to be consistent with declining heights as pay rises, though, we must go further. We hypothesise a negative relationship between height and "civilian preference" (i.e., τ). Such a correlation is not implausible, and could arise indirectly, for example if literate, newspaper-reading, property-owning individuals were more politically engaged and more likely to have a strong commitment to the abstract notion of preserving the union, and were also taller.

2.3 *A model with patriotism*

The basis of the Bodenhorn, Guinnane, and Mroz model is the potential volunteer's comparison of utility in civilian and military life. This depends on the natural logarithm of wages and τ, or preference for civilian life.[6] Wages, in turn, depend on civilian skills, military-specific skills, and height.

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[6] Bodenhorn, Guinnane, and Mroz imagine two preference variables, τ_C and τ_M, one for each alternative career, but it is the difference between the two that counts. We consider a single variable τ that describes preference for civilian life.

Beyond reintroducing τ, we make several further changes to Bodenhorn, Guinnane, and Mroz's model. We simplify by omitting military-specific skills (ε_M in their notation). "Skills" should be understood as shorthand for human capital here. Bodenhorn, Guinnane, and Mroz's formulation of the model is meant to describe an individual considering a career in the military, over the course of which there may be a differential payoff to military-specific skills in the form of promotions to higher ranks with higher pay. Our concern here is instead with soldiers enlisting as privates in the expectation of serving a single term.

We also remove the links between military pay and civilian-specific skills (ε_C in Bodenhorn, Guinnane, and Mroz's notation, simply ε here) as well as with height. All (white) privates received the same pay of $13 per month, the same Federal enlistment bounty, and a local bounty that depended on when and where they enlisted but not their personal attributes. There was no differential pay based on their civilian skills, nor any return to height *per se*. We model the link between height and civilian wages as arising only indirectly, through a common correlation with skills ε. Table 2.1 summarises our notation.

Table 2.1. Model notation

Symbol	*explanation*	*role*
α_C, α_M	base pay by sector	constants
$\alpha = \alpha_C - \alpha_M$	civilian base pay advantage	" "
ε	skills, or human capital	normal random variable
τ	preference for civilian life	" "
$\eta = \varepsilon + \tau$	civilian advantage	" "
w_C, w_M	wage by sector	" " ; constant
H	height	normal random variable
μ_X	mean of variable *X*	constant
σ_X, σ_X^2	standard deviation (variance) of *X*	" "
ρ_{XY}	correlation of variables *X* and *Y*	" "
ϕ, Φ	standard normal density and cumulative distribution	functions

An individual volunteers if the utility of military life exceeds that of civilian life:

$U(C) \leq U(M)$, or alternatively $U(C) - U(M) \leq 0$, where

$U(M) = \ln(w_M)$, and $U(C) = \ln(w_C) + \tau$.

Wages depend on base pay and human capital[7]:

$\ln(w_M) = \alpha_M$; $\ln(w_C) = \alpha_C + \varepsilon$.

Substituting for wages in the utility functions yields the condition for volunteering:

[7] Bodenhorn, Guinnane, and Mroz's formulation envisions a coefficient δ on skills, but this is set to a value of one in their simulations. We simply omit δ.

$(\alpha_C + \varepsilon) + \tau - (\alpha_M) \leq 0$, or

$\eta \leq -\alpha$,

where $\eta = \varepsilon + \tau$ is the random element in the decision, varying across individuals, and $\alpha = \alpha_C - \alpha_M$ is the civilian advantage in base pay. ε, τ, and thus also η, are assumed to be normally distributed. Note that

$$\mathrm{E}(\eta) = \mathrm{E}(\varepsilon) + \mathrm{E}(\tau) = \mu_\tau.$$

Heights are assumed to be normally distributed, so that h and η are draws from a bivariate normal distribution. This joint distribution among military volunteers is truncated: we observe only the part of the distribution for which $\eta \leq -\alpha$. This should not be confused with truncation arising from a minimum height requirement, which does not play a role in the model, though it is relevant for our empirical work. The marginal density of one variable from a truncated bivariate normal distribution can be found in statistics texts (Kotz et al., 2000, p. 311, Balakrishnan and Lai, 2009, p. 532). In our case, the probability density for military heights is given by Equation 1.

Eq. 1. $$p(h) = \phi\left(\frac{h-\mu_h}{\sigma_h}\right) \cdot \frac{1}{\Phi\left(\frac{-\alpha-\mu_\tau}{\sigma_\eta}\right)} \cdot \Phi\left(\frac{(-\alpha-\mu_\tau)/\sigma_\eta - \rho_{h\eta}(h-\mu_h)/\sigma_h}{\sqrt{\left(1-\rho_{h\eta}^2\right)}}\right)$$

Equation 1 looks formidable, but is conceptually straightforward. The first term is the unconditional distribution of heights, expressed in standard-normal terms. The second has in the denominator the unconditional probability of volunteering, again standardised. This term normalises the density to integrate to one but does not change the relative probability of different heights. The third term is the conditional probability of volunteering, given height (again, in standard-normal form). It depends on ρ, the correlation of height with η, and is decreasing in height if $\rho > 0$. μ_τ appears in the second and third terms because it is the expected value of η.

2.4 *Technical details*

Given particular parameter values, we can use Equation 1 to calculate moments of the military height distribution analytically. We also make use of numerical simulations when examining the separate roles of τ and ε (which makes the relevant distribution a more difficult trivariate normal), and when considering the way early recruitment can deplete the pool of potential volunteers available later.

In choosing parameter values we adopt varying criteria, in some cases following Bodenhorn, Guinnane, and Mroz, in other cases appealing to evidence, in still other cases simply trying to make the model's predictions consistent with the evidence. In most cases, we cannot defend the precise values selected. What we can argue is that they are plausible: plausible enough that the predictions we generate cannot be rejected on theoretical or *a priori* grounds, but only on the basis of historical evidence. This is the same rationale as Bodenhorn, Guinnane, and Mroz invoke in their own simulations.

Table 2.2. Model parameter values

σ_h	2.5	$\rho_{\tau\varepsilon}$	-0.20
σ_ε	0.225	$\rho_{\tau h}$	-0.10
σ_τ	0.25, 0.50, 0.125	$\rho_{h\varepsilon}$	0.20
μ_h	66.0	σ_η	0.30, 0.51, 0.23
μ_ε	0.0	$\rho_{h\eta}$	0.07, -0.01, 0.14
μ_τ	0.4		
α	0.30, 0.00, -0.20		

Table 2.2 sets out the values used in what follows. In the cases where three values are given, these correspond to the pre-war, early-war, and late-war periods. The mean and variance of heights we take from Bodenhorn, Guinnane, and Mroz. The variance of skills is chosen to generate the same variance in civilian log wages as in a typical simulation of Bodenhorn, Guinnane, and Mroz.[8]

The correlation between height and skills is chosen so as to generate a 1.8% increase in expected wages for each one-inch increase in height. That is a plausible value on the basis of studies using late 20th century data, as reported for example by Case and Paxson (2008; Table 1). Recalling that civilian log wages rise one for one with skills, ε, we exploit the formula for the conditional expectation of a bivariate normal variable:

$$E(\varepsilon|h) = \mu_\varepsilon + \rho_{\varepsilon h}\frac{\sigma_\varepsilon}{\sigma_h}(h - \mu_h),$$

and solve for $\rho_{\varepsilon h}\frac{\sigma_\varepsilon}{\sigma_h} = 0.018$.

The correlations of τ with skills and with height were chosen as not-implausibly-large round numbers that generated the desired sort of model behaviour. The correlation of τ with height is the smaller of the two because we hypothesise that it arises only indirectly as described earlier. The initial standard deviation of τ, 0.25, was chosen to generate a pre-war flow of volunteers into the army that was very small: 1% of the relevant population. The pre-war army was tiny – only about 16,000 men – and was not known as an elite organisation that accepted only a small fraction of would-be volunteers.

[8] Given their assumptions about covariances and coefficients, $\text{var}(\ln w_C) = \beta_C^2 \text{var}(h) + \text{var}(\varepsilon_C)$ in the Bodenhorn-Guinnane-Mroz model. Using typical values $\beta_C = 0.04$, $\text{var}(\varepsilon_C) = 0.04$, and var($h$)=6.25, this evaluates to 0.05. This value looks low by today's standards but may be appropriate for the mid-nineteenth century

We model the waxing and waning of patriotism as changes in the *variance*, rather than the mean of τ. As the variance of τ increases, so does that of η (since $\text{var}(\eta) = \text{var}(\varepsilon) + \text{var}(\tau) + 2\text{cov}(\varepsilon, \tau)$). Meanwhile, the correlation $\rho_{h\eta}$ is driven down as the negative relation between height and civilian preference comes to outweigh the positive relation between height and skills. In reality, increasing the variance of τ is not an increase in patriotism but an increase in the strength of feeling on both sides of the mean: both patriotism and its opposite. But since men in the upper part of the τ distribution will never volunteer anyway, whether their τ value is 1 or 10, our mean-preserving spread can be seen as a shortcut way of modelling an asymmetric change in the distribution.

2.5 *Simulating the Civil War*

The results of our simulation exercise are presented in Table 2.3. The mean and standard deviation of height are calculated analytically using Equation 1. The means of the skill and civilian preference variables are instead derived from numerical simulations based on 500 repetitions drawing a hundred thousand observations from a trivariate normal distribution of h, ε, and τ.

Few men (just 1%) find military service attractive before the war; the model was calibrated to yield this result. The mean value of civilian preference is equivalent to a 40 log point (49%) wage premium, but in the pre-war simulation the military pays 30% *less* than an average-skill man can earn in the civilian economy. Only men with low skills (1.5 standard deviations below the mean, on average), and very low civilian preference (1.8 standard deviations below the mean) enlist. This sort of selection on ε and τ implies negative selection on height. At 65.56”, mean height in the army is 0.44” below the population mean.

Table 2.3. Simulated volunteer height distributions

	pre-war	early-war	late-war	late-war depletion
mean h	65.56	66.04	65.51	65.22
sd(h)	2.53	2.50	2.53	2.46
enlistment rate	0.01	0.21	0.20	0.10**
mean ε	-0.35	-0.08	-0.27	-0.34
mean τ*	-0.05	0.09	0.28	0.51

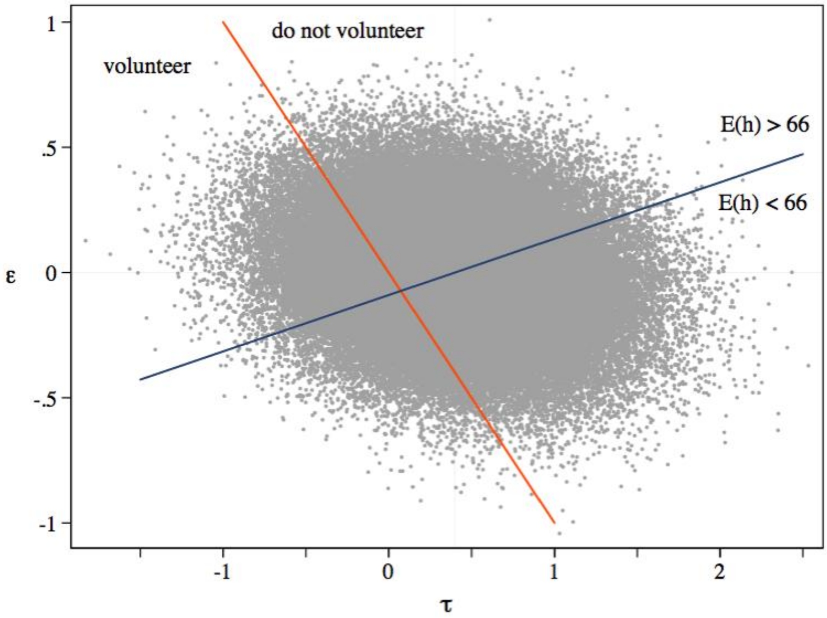
Note: The scenario labelled “late-war depletion” refers to a simulation of late war enlistment when the previous enlistment of earlier volunteers is explicitly taken into account.
* For the sake of comparability, the means for τ are reported on a constant basis, as if σ_τ were constant at 0.25.
** 10% of the pool remaining after early recruitment; 7.8% of the initial population.

We simulate the early war as a surge of patriotism, complemented by a non-trivial increase in military pay, which now matches civilian income for the average-skill man. The rate of voluntary enlistment jumps twenty-fold, to about one in five eligible men. In terms of skill, volunteers are now about average. In terms of patriotism, they are not, with a typical value of civilian preference about 1.25 standard deviations below the mean. (For comparability, the figures for average τ in Table 2.3 are standardised to the original distribution, with a standard deviation of 0.25. Recall that μ_τ remains unchanged at 0.4 throughout. Alternatively, think of the reported mean as referring to the "original" τ.) The negative selection on skills and positive selection on patriotism cancel each other, so that there is no selection on height.[9]

Figure 2.1 helps make clear what is going on. The cloud of points represents one draw of 100,000 observations from the joint (τ, ε, h) distribution. In other words, each point represents one potential volunteer. The black lines in the background denote mean skills (0) and mean civilian preference (0.4). The downward-sloping orange line represents the decision margin for enlistment: $\eta = \varepsilon + \tau = -\alpha$. To its left, low skill makes the opportunity cost of military service low and low civilian preference makes it relatively attractive. The upward-sloping blue line represents values of τ and ε for which the expected value of height is just equal to the population mean of 66". Below this line, strong civilian preference and low skills are associated with average heights below the population mean.

[9] More precisely, it is negative selection on civilian preference rather than positive selection on patriotism. We will use these formulations interchangeably.

Figure 2.1. Skills, civilian preference, and military service in the early war



Note: The figure plots 100,000 draws from a simulated bivariate normal distribution of skills (epsilon) and preference for civilian employment (tau) consistent with the early war scenario described in the text. The expectation of height equals the population mean of 66" along the upward sloping line. Along the downward-sloping line individuals are just indifferent between enlisting in the military and remaining in civilian employment."

The figure shows that early-war volunteers are almost all below mean civilian preference: only a bare handful of points are to the right of an (imaginary) vertical $\tau = 0.4$ line and simultaneously below the orange line. With respect to skill, though, things are more balanced, with a significant share above-average. In this sense, it is patriotism that dominates the decision to enlist in the model. Finally, the observations in the volunteer area of the graph lie equally above and below the expected height = 66" line, illustrating the absence of selection on height.

We model the later stages of the war as the distribution of civilian preference shrinking back in on itself. (Again, this could be seen as a shortcut method for modelling an asymmetric change in the distribution's shape.) Very few men are motivated by patriotism alone to enlist, and the authorities respond by raising military pay to well above the average civilian level. This elicits a continuing flow of recruits at the same rate as in the early war, but the type of men changes. It is men with much lower skills (1.25 standard deviations below the mean, on average), hence low civilian incomes, that are motivated to enlist despite their preference for civilian life. In this sense, late-war enlistment is economically and not ideologically motivated in the model. The net effect is that mean height among volunteers falls by half an inch relative to the early-war and population means.

This effect is even stronger if the pool of potential recruits is fixed at the beginning of the war and gradually depleted. In this case, the most ardent patriots enlist early and are no longer available. This scenario is illustrated in the rightmost column in Table 2.1 labelled "late-war depletion". The late war military pay raise (which lowers the civilian advantage α from 0 to -0.2) is no longer sufficient to maintain an adequate flow of recruits, which drops to half or less its former level. And those who do volunteer must be drawn from further up the civilian preference distribution (the real patriots having already enlisted), where only even lower skill levels and incomes make the military an attractive proposition. Mean height falls to 65.22", eight tenths of an inch below the early-war or population mean.

For the late war, then, the historical record, the height data, and the model agree that negative selection on height was probable. This effect did not operate via age, however, and could not have induced a spurious decline in heights among late-war recruits. In other words, toward the end of the war those who entered the military were shorter at all ages (for all birth-years) by a comparable amount and as a consequence the trend in height in this group is not at all different from those who entered the military earlier in the war. For the early war, there is no suggestion in the testimony of contemporaries that volunteers were in any sense below average, whether this refers to strength and stature, intelligence and education, income, or courage.[10] Our simulation results show that an absence of selection on height is entirely plausible for this phase of the conflict. For this period, both the level and trend in military heights were representative of the underlying population.

3. Civil War statures – the evidence

In this section we first discuss our replication of Bodenhorn, Guinnane, and Mroz's empirical analysis and how their findings depend on mistakes in the analysis. We subsequently introduce improvements in both the data and in the regression specifications, and find negative trends in mean height across the 1830s in several recruiting periods, some of them quite short, and groups for which changing selection on height was not an issue.

3.1 *The critics' evidence*

[10] In a personal communication James McPherson of Princeton University, Pulitzer-Prize winning author of *Battle Cry of Freedom: The Civil War Era*, confirmed this assertion.

Bodenhorn, Guinnane, and Mroz investigate the possibility of selection effects in the Union Army data by regressing height on birth year and either age or enlistment year. In the absence of selection effects, they reason, height's variation with changing environmental conditions should be picked up by birth-year; there is no reason to expect enlistment year or age (among adults) to have any additional predictive power. Statistically significant estimated effects of these controls would be strongly suggestive of selection effects that varied by age or enlistment year. So too would be changes in estimated birth-cohort effects when the controls are added. (Constant selection, unvarying with age or enlistment year, would not be detected by this diagnostic.)

To implement their tests, Bodenhorn, Guinnane, and Mroz extract heights and estimated birth years of white soldiers aged 23-30 from the Union Army dataset maintained by ICPSR (Fogel et al., 1990). They find that age and enlistment-year dummy variables are jointly statistically significant in all samples they consider and argue that this is prima facie evidence of selection effects. Interactions of age and birth-cohort too are jointly significant in all cases, implying different time trends by age (alternatively: different age-effects by time). Enlistment-year interactions with birth-cohort are jointly significant in their primary sample.[11]

Bodenhorn, Guinnane, and Mroz call attention to the change in the estimated time trend that results from including enlistment year controls. Their naïve OLS regression of height on birth cohort yields a strong and statistically significant downward trend: the estimated effect of 1842 birth is −1.35" relative to 1831 birth. But when they add enlistment year controls the trend evaporates. An almost monotonic, steeply sloped path becomes mostly flat and mostly statistically insignificant. This is unexpected because prior researchers also included enlistment-year controls without affecting the downward trend (A'Hearn, 1998; Margo and Steckel, 1983).

3.2 *Replication and revision of Bodenhorn, Guinnane, and Mroz's regressions*

[11] Bodenhorn, Guinnane, and Mroz distinguish three samples depending on the way age is estimated. In the first and largest, they simply use declared enlistment age (also obtaining birth year by subtracting this from year of enlistment). In a second they rely instead on a directly declared birth date, which they subtract from the enlistment date. This information is available for a minority of recruits. The third and smallest sample is the set of soldiers for which the two measures are both available and agree. They conduct their tests separately using the declared-age, calculated-age, and consistent-age samples.

We are able to replicate Bodenhorn, Guinnane, and Mroz's results exactly.[12] But the exercise reveals problems with their method, and the spurious statistical artefact in the analysis turns out to be not the negative trend, but its seeming disappearance. For Bodenhorn, Guinnane, and Mroz make two crucial mistakes. First, they fail to truncate the height data appropriately. The Union Army had a minimum height requirement, although it does not always show up clearly in the data, because it changed during the war and was inconsistently enforced. This problem of a deficient lower tail in the distribution, known as shortfall, biases OLS and makes the estimated trends unreliable insofar as part of the distribution is missing to varying degrees on account of the recruiting procedures (Komlos and Kim, 1990; Heintel and Baten, 1998; A'Hearn, 2004; Komlos 2004; Horrace, 2015). Among recruits aged 23 and older, the share below 64" increased from 4.3% in 1861 to 8.3% in 1865, so inclusion of sub-minimum heights has the potential to bias enlistment year and birth cohort effects. Truncating the data at a relatively high minimum is the safest way to avoid biasing the trend estimates. We choose 64".[13]

An even more significant and quantitatively more important problem with Bodenhorn, Guinnane, and Mroz's analysis than truncation is that they fail to distinguish native-born and immigrant soldiers.[14] This might be appropriate for verifying the presence of selection effects, which ought to affect immigrants too. However, it is certainly not appropriate for verifying the existence of an antebellum puzzle, a proposition which always referred to the native-born only. Immigrant soldiers were shorter than native born ones and as a consequence their inclusion can bias the trend, depending on their share among the various birth cohorts.

We present our revised regressions based on Bodenhorn, Guinnane, and Mroz's specifications in Appendix Tables 1-3. The only differences are that we exclude foreign-born recruits and truncate the sample at 64" as described above. Like Bodenhorn, Guinnane, and Mroz, we find that age (Table A1, panel B) and enlistment year effects are jointly

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[12] Strictly speaking, our replications are *exact* only for the primary sample, using declared ages. In the samples with calculated and verified ages our results are very close.

[13] The statutory requirement was 64.5" at the war's beginning, but was reduced to 63" in August 1861. It stayed at that level until 1864, when it was reduced to 60" (Baxter, 1875, p. 40). A tendency to round measurements to the nearest inch and the "heaping" of frequencies on attractive numbers complicate identification of shortfall. We choose 64" because it is (almost) the highest statutory requirement and because there are some distributions that appear deficient below it, for example men aged 23+ enlisting in 1862.

[14] We have estimated the model with only-truncation and only-immigrant exclusion and the latter had a larger impact on the trend.

statistically significant (Table A2, panel B) in separate regressions**.** Unlike these authors, however, we do not find that these controls make the antebellum puzzle disappear. Figure 3.1 follows Bodenhorn, Guinnane, and Mroz (in their Figure 2) in plotting the two series of birth-cohort effects: a set of baseline estimates (Table A1, panel A) and estimates with enlistment-year controls (Table A2, Panel B).

Fig. 3.1. Revised estimates of birth cohort effects with enlistment year controls

Note: Plotted are birth-cohort effects from OLS estimates of Bodenhorn, Guinnane and Mroz' model. Baseline model from Table A1, panel A; model with enlistment-year dummy variables from Table A2, panel B. Effects are expressed as deviations from the reference of 1831. The estimating sample has been revised to include only native born men aged 23-30 with heights in excess of 64 inches.

The estimates with enlistment year controls show a clear downward trend, cumulatively declining by some 0.90 inches. The estimates for 1838, 1839, 1841, and 1842 are all statistically significant at the 5% level. In other words, it is Bodenhorn, Guinnane, and Mroz's failure to exclude foreign-born soldiers and to appropriately take account of minimum height requirements that generates their spurious finding that heights did not decline.

The annual trends controlling for enlistment effects are reported in Figure 3.2. The results indicate a progressive downward shift of the mean height series for later enlistment years. The time trends are common, determined by the birth-cohort effects.[15] Figure 3.3 illustrates the trends when they are allowed to differ by including enlistment-year – birth-year interactions, as in Table A3.

[15] Mean heights for each year are plotted only over the relevant range of birth cohorts: 1831-1838 for enlistment-year 1861, for example. Recall that Bodenhorn, Guinnane, and Mroz restrict the sample to ages 23-30. Men born in 1839 had not reached 23 by 1861 and are first observed in the sample in 1862.

Both figures 3.2 and 3.3 indicate clearly a (statistically significant) decline in mean military heights of about half an inch between 1861-62 and 1863-65. The periodization corresponds neatly to that outlined in Section 2.1, in which the Enrollment Act in March 1863 marks a dividing line between an early period of fairly successful volunteer recruitment and a later period in which officials addressed a crisis in morale with the carrot of rising enlistment bounties and the stick of Federal conscription. As our model predicts, the later period seems to have been characterised by significant negative selection on height.

Fig. 3.2. Revised estimates of height trends by enlistment year

Note: Plotted are predicted heights from OLS estimates of the model of Bodenhorn, Guinnane and Mroz with enlistment-year dummy variables (Table A2, panel B). The separate series for each enlistment-year combine the regression constant, the enlistment year effect, and birth-year effects. The estimating sample has been revised to include only native born men aged 23-30 with heights in excess of 64 inches.

Fig. 3.3. Revised estimates of height trends if birth cohort effects vary by enlistment-year

Note: Plotted are predicted heights by enlistment year, derived from OLS estimates of the model of Bodenhorn, Guinnane, and Mroz with interactions between birth-year and enlistment-year (Table A3). The estimating sample has been revised to include only native born men aged 23-30 with heights of at least 64 inches. Predicted height is the sum of the regression constant, enlistment year effect, birth-year effect, and enlistment-year – birth-year effect. The trends have been smoothed to make the graph more easily legible, using locally weighted regression with a bandwidth of 0.8.

Equally clear in Figures 3.2 and 3.3 is the fact that the advent of negative selection on height is not the cause of a spurious downward trend in mean height. For falling mean heights are observed *within* each enlistment year, and these are periods too short for the relative military pay or the distribution of civilian preference to be changing dramatically. (1863 in Figure 3.3 looks like a possible exception, but its trend there is based on just 332 soldiers.)

That the height of black troops taller than the 64 inch height standard and recruited in 1863 and 1864 was 67.4 inches but those recruited in 1865 were 0.5 inches shorter is yet another indication that economic conditions were not playing a major role in the recruitment process. The reason is that it is not at all likely that economic prospects of the ex-slaves changed noticeably in this short interval.[16]

In Figure 3.4 we present a final set of revised Bodenhorn, Guinnane, and Mroz estimates – those for the model with age controls and a common birth-cohort trend (Table A1, panel B). While the estimates are supportive of our claim that the antebellum puzzle is not a statistical artefact, what we see in Figure 3.4 is a cautionary tale about the intractable problem of collinearity between age, birth year, and enlistment year. The declines in predicted mean height – roughly an inch in just five years for any particular age in Figure 3.4, or –2.34" from 1831 to 1842 based on the birth cohort effects in Table A1, Panel B – are too steep to be plausible and have clearly been contaminated by enlistment year effects. The way this works is most obvious at the extremes. 1842 births are observed only for 23-year olds, but also only in recruitment-year 1865. 1841 births are observed only for 23 and 24 year olds, but these correspond exactly to 1864 and '65 enlistments.

[16] Haines et al (2011) report a decline in height of 0.8 inches among those who enlisted in 1865; however, that includes all recruits, not only those above the minimum height requirement.

Fig. 3.4. Revised estimates of height trends by age

Note: Plotted are mean heights from OLS estimates of the model of Bodenhorn, Guinnane and Mroz with age dummies (Table A1, panel B). The estimating sample has been revised to include only native born men aged 23-30 with heights in excess of 64 inches. The separate series for each age combine the regression constant, age effect, and birth-year effect.

More generally, since birth year plus age at enlistment must equal enlistment year exactly, it is impossible to control for both birth cohort and age simultaneously and one must choose. There is good historical evidence that the character of recruits changed over the war and none that it differed by age. Theory – on a simple reading of the Bodenhorn, Guinnane, and Mroz model – suggests more *negative* selection among older men, not the +1" advantage that Table A1, Panel B implies for 30 year olds relative to 23 year olds. That is a reflection of the enlistment year effect. For a given birth year younger men are taller because they enlisted earlier in the war when higher status men had a higher propensity to enlist. For these reasons we consider only enlistment-period effects in what follows.

3.3 *Improved estimates of the trend in the height of Union Army soldiers*

In this section we estimate time trends for several alternative periodisation of the War. We also improve on Bodenhorn, Guinnane, and Mroz's approach in other respects. Continuing to focus on native born men and to truncate the estimation sample at 64", we now add controls for birth region and occupation in all regressions which they failed to do, leaving themselves open to omitted variable bias. There were fluctuations in sample composition over the course of the war so that it makes sense to control for it: the increase in the share of farmers from 54% to 61%, in 1865, or the decline in New England's share from 12 to 4%, for example. We also consider a broader range of ages, from 18 to 50, adding controls for ages 18-21 when many young men were still growing to the list of regressors. There is no reason to limit the sample to 30-year olds, as Bodenhorn, Guinnane, and Mroz do, insofar as it makes sense to utilize all the available information in the sample.

We also revisit the Union Army records, taking greater advantage of their richness to construct a dataset that is more accurate, larger, and includes more characteristics of recruits.[17] We are thereby able to increase the number of observations by a factor of three from roughly 7,300 to 23,700 enabling us to estimate the trend with greater accuracy.[18]

Estimates of a baseline model are presented in Table A4 and Figure 3.5a. Control variable effects are as might have been predicted on the basis of previous work with the Union Army data. Soldiers from the mid-Atlantic and New England were shorter by about half an inch than those from the South and West. Farmers were about half an inch taller than other occupations. And young men seem to have still been growing up to age 20, with effects estimated at -0.78”, -0.32”, -0.11”, and -0.05” for ages 18-21. The controls, and the much larger sample, do not eliminate enlistment-year effects, which remain strong. The recruits of 1865 were about half an inch shorter than those of 1861, all other things constant. Neither do they eliminate a clear downward trend in heights, however. The timing and magnitude of the decline in height emerge more clearly over the longer time span now under study.

As shown in Figure 3.5a for enlistment years 1861 and 1865, heights are stable through the 1820s before beginning to fall in the early 1830s; the cumulative decrease approaches an inch by the mid-1840s. We have also estimated the model with interactions between enlistment-year and birth-year, which yields very similar time trends for each enlistment year, as illustrated in Panel B of Figure 3.5.[19] It is interesting to note that the downturn in heights appears to have begun somewhat earlier among the recruits of 1864 and 1865, who arguably were of lower socioeconomic status even conditioning on

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[17] The Union Army data include multiple observations on most variables: up to two birth dates, five heights (and associated dates), six enlistment and muster dates, up to twenty (!) pension applications with ages, dates, literacy, and other information. Unfortunately, the data were not always entered according to plan – information was not always entered in chronological order, for example – but with some care the multiple observations allow for cross-checking, the identification of errors, and the filling in of missing values. We are able to identify not just a date of enlistment, but the date of the first wartime enlistment. We can observe or infer not just age at enlistment but age at the time height was measured, which is not always the same. We create measures of illiteracy (from self-declarations on pension applications), of misconduct such as desertion (from military court records), and of the recruit’s status as a volunteer, draftee, or substitute.

[18] The original data set has some 39,000 observations. The difference between it and the number of records in the working data set is made up of those who were foreign born, shorter than the minimum height requirement, were younger than 18 or older than 50.

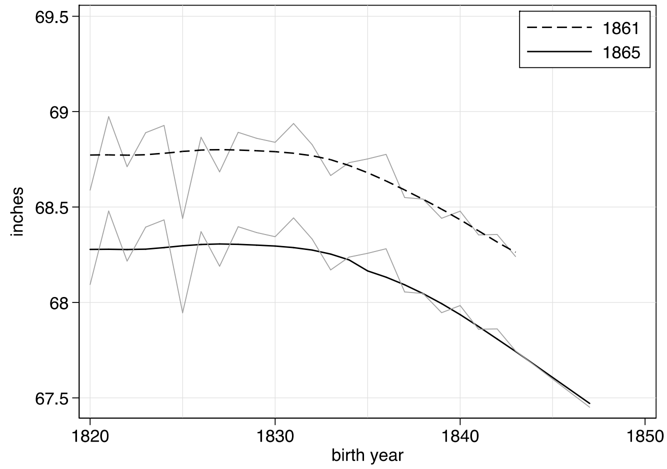
[19] As there are 108 estimated interaction effects, we do not present the full set of estimates in tabular form.

observables and therefore would have felt the increases in food prices earlier. (The irregular trend of 1863 is again based on a very small sample.[20])

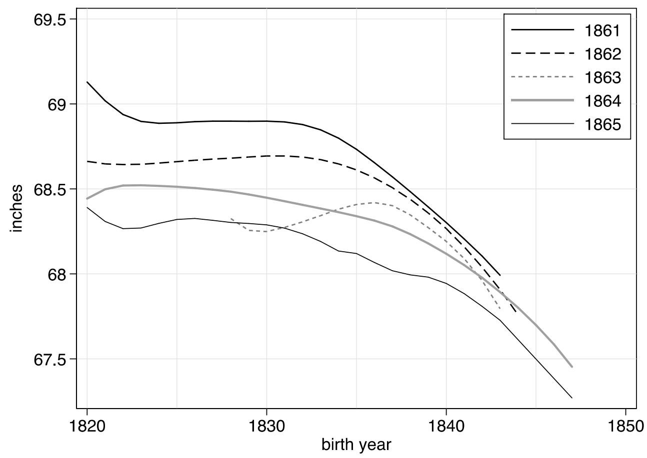
Our reading of the statistical and historical evidence identified a watershed in March 1863, when passage of the Enrollment Act established Federal conscription for the first time.[21] Before this, the Army was successful in attracting volunteers without recourse

Fig. 3.5. New estimates of height trends by enlistment year

A. Common trends



B. Varying trends by enlistment-year



Note: Plotted are predicted heights from an OLS regression of height on dummies for age at measurement, enlistment-year, birth-year, birth-region, and occupational group. The estimating sample is native-born recruits aged 18-50 at measurement with heights of at least 64 inches. Panel A estimates from Table A4 are the sum of the regression constant, birth-year effect, and enlistment year effect. The thin gray lines reflect annual birth cohort effects; the thick, darker lines are smoothed versions of the same. Estimates for 1862-64 omitted to enhance legibility. Panel B estimates from a model with interactions of birth-year and enlistment year, allowing for different trends by enlistment year (tabular presentation omitted due the number (108) of interaction effects). Plotted series have been smoothed by locally weighted regression with a bandwidth of 0.8; series for 1863 plotted only for

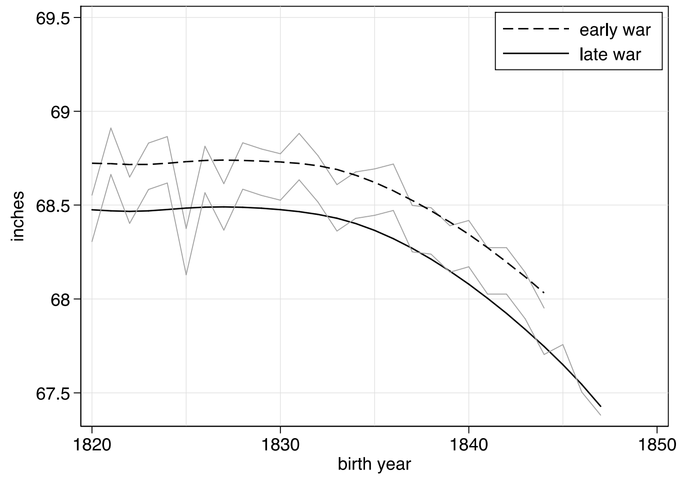
[20] Only 10 enlistment years have more than 50 observations, which are really inadequate for estimating the trend accurately.

the birth-years with at least 20 observations (1828 onwards). In both panels the reference is a mid-Atlantic-born farmer aged 22 or more.

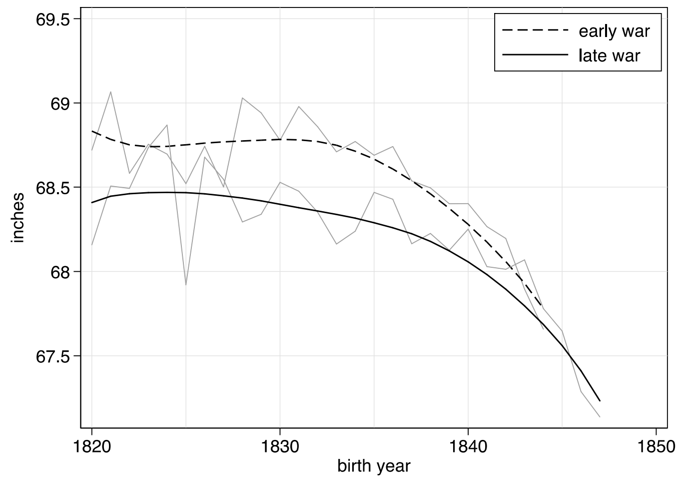
to extraordinary measures. Afterwards, low morale and depletion of the pool of patriotic men, meant that only the threat of the draft and lure of rising enlistment bounties could sustain a flow of recruits. Estimates of a model with early- and late-war enlistment effects are presented in Table A5. Predicted mean heights are plotted in Figures 3.6a and 3.6b.

Fig. 3.6. New estimates of height trends by recruiting regime

A. Common trends



B. Regime-specific trends



Note: Plotted are predicted heights from an OLS regression of height on dummies for age at measurement, birth-year, birth-region, occupational group, and recruiting regime. Early- and late-war recruiting regimes refer to the periods April 1861-February 1863 and March 1863 – May 1865, respectively. The estimating sample is native-born recruits aged 18-50 at measurement with heights of at least 64 inches. Panel A estimates: Table A5, Panel A, summing the regression constant, birth-year effect, and recruiting regime effect. Thin gray lines reflect annual birth cohort effects; thick, darker lines are smoothed versions of the same. Panel B estimates: Table A5, Panel B model with interactions of birth-year and recruiting regime. The plotted series have been smoothed by locally weighted regression with a bandwidth of 0.8. In both panels the reference is a mid-Atlantic-born farmer aged 22 or more.

Both Table A5, panel A and Figure 3.6, panel A refer to a model with common birth cohort effects, while Panel B allows for interactions between enlistment-period and birth-cohort. The time trends are familiar: declining**,** highly statistically significant, and present in both sub-periods.[22]

It is not the existence of selection effects but their change over time that could in principle produce spurious fluctuations in mean height estimates. Our enlarged sample allows us to zoom in on brief recruiting periods–periods as short as 90 days—during which there was very little scope for changes in labour market conditions and associated selection pressures.[23] Three such trimesters can be identified, during which at least 2,500 useable observations are available: 14 August – 11 November 1861 (n=3,736); 11 July – 9 October 1862 (n=7,133); and 6 August – 4 November 1864 (n=2,703). None of these periods overlap and they lie on either side of the introduction of the draft. Separate estimates for each of the three windows are presented in Table A6. The time trends are plotted in Figure 3.7. Yet again the estimates show stable heights in the 1820s followed by a decline beginning in the early 1830s. The declining trend in military heights is clear, and clearly statistically significant (Figure 3.7).[24]

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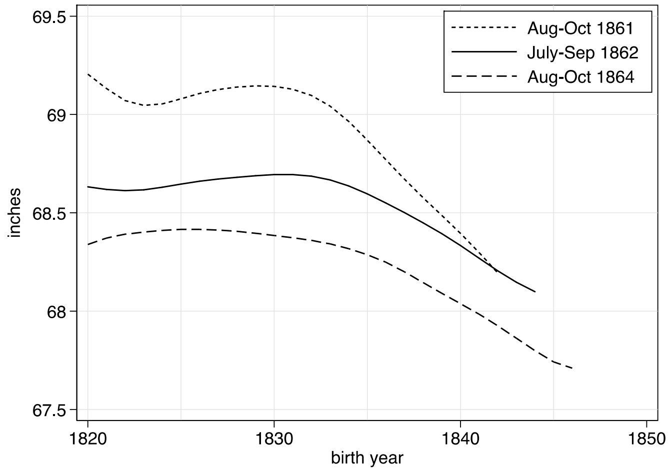
[22] When we add to the regressions in Table A5 dummy variables for illiteracy, being charged for breaches of military discipline, and draftee or substitute status, we find that all four have negative effects on height. Though statistically significant at the 1% level except for substitute enlistment, the effects are small: in the range of -0.1” to -0.2”. The inclusion of these controls has no impact on the estimated time trend.

[23] A similar strategy was suggested by Baten (2015).

[24] In the third 90-day period, only two cohort effects are individually significant: 1826 (+) and 1847 (-). The 1840s birth year effects are jointly statistically significantly negative (i.e. less than the 1840 reference).

Fig. 3.7. New estimates of height trends by 90-day recruiting window

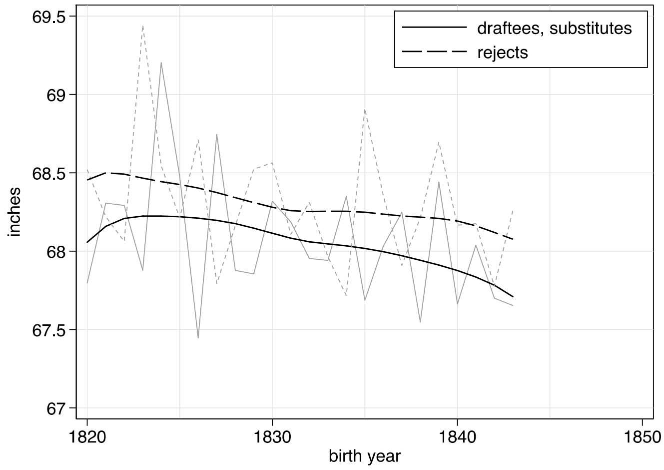


Note: Plotted are predicted heights from separate OLS regressions of height on dummies for age at measurement, birth-year, birth-region, and occupational group, for the 90-day enlistment periods indicated in the legend (Table A6). The series have been smoothed by locally weighted regression with a bandwidth of 0.8 to improve legibility. Predicted height is the sum of the estimated regression constant and birth-year effect. The estimating sample includes native-born men aged 1850 at the time of measurement, with heights of at least 64 inches. The reference is a mid-Atlantic born farmer aged 22 or more.

3.4 *Height of draftees, substitutes, and rejects*

Thus far we have considered time periods during which selection effects were constant. We can apply the same strategy to different groups, in particular to draftees and their substitutes, and to recruits rejected by the army. Because exceptionally patriotic men would have a tendency to volunteer, and because it was always possible to furnish a paid substitute or (initially) to pay a commutation fee rather than serve directly, relatively poor men were always overrepresented among draftees. Similarly, substitutes were economically motivated and it was those with limited outside opportunities that found the substitute fees and enlistment bounties most attractive. Even conditioning on occupation, then, we would expect negative selection on income, and thus height, in this group.

Fig. 3.8. New estimates of height trends among draftees, substitutes, and rejected recruits



Note: Plotted are predicted heights from OLS regressions of height on dummies for age at measurement, birth-year, birth-region, occupational group, and substitute status or enlistment year as relevant (Table A7). Samples are restricted to native-born men aged 18-50 at measurement, with heights of at least 64 inches, who enlisted as draftees or substitutes (solid lines), or who were rejected by the army (broken lines). Thin gray lines illustrate annual birth cohort effects; thicker, dark lines are smoothed using locally weighted regression with a bandwidth of 0.8. The reference is a mid-Atlantic-born farmer aged 22 or more enlisting late in the war.

Table A7, panel A and Figure 3.8 show that the time trend among roughly 1,900 draftees and substitutes is negative. Mean height decreases from 1830 to the early-1840s by about half an inch, even among a group subject to constant, strongly negative selection. We can estimate the same regression for a sample of approximately 1,300 men – not part of the Union Army sample – who were rejected by the army on grounds of poor health or physical condition.[25] Like the draftees, these men cannot have been well-off, on average, by virtue of the same physical failings or ill health that motivated their rejection. The estimates of Table A7, Panel B, and the broken line plot in Figure 3.8 show that among army rejects, heights were of a similar level, and followed a similar decreasing trend, as among draftees and substitutes. In both these disadvantaged groups, mean heights appear to be decreasing even before the early 1830s, which we also see in other sub-samples of late-war recruits.

3.5 *Estimates of Population mean heights*

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25 The dataset is available from ICPSR (Fogel and Steckel, 1995):. The most common health problems, each responsible for at least ten percent of rejections, were: tooth disease, injuries and physical disabilities, skeletal and joint problems, and hernias. Among 1,316 potentially useable observations, enlistment year was 1864 or ’65 in 605 cases, missing in the remaining 511 cases. Where enlistment year (and hence also birth year) was missing, we assumed 1863. A downward trend in heights is also found in the smaller sample of ca. 750 men for which enlistment year is available.

The regressions discussed so far have the limitation that they permit statistical inference only about the trend in the height of soldiers, not of the underlying population. We have established that changing selection effects did not generate a spurious negative trend in the height of soldiers. That trend was real, and the only plausible interpretation is that heights were falling in the population, but to this point we have neither an exact estimate of the magnitude of that change nor a reliable way of stating confidence in our findings.[26] The OLS estimator in a truncated sample is therefore inconsistent, its distribution unknown – even the direction of bias, though experience suggests it is usually towards zero. Our statements about statistical significance (like those of Bodenhorn, Guinnane, and Mroz in their empirical work) are therefore inferences about the probabilities that observed differences among soldiers are due to chance.

Our reading of the evidence is that in the early phase of the Civil War, prior to the Enrollment Act of 1863, negative selection on height was not just non-varying, but non-existent. For this period, random sampling from a normally-distributed population above a minimum height requirement is a reasonable assumption, and we can employ truncated maximum likelihood estimation (TMLE). TMLE is consistent and has asymptotically normal standard errors, allowing us to estimate population parameters and undertake hypothesis testing. Table A8 and Figure 3.9 show TMLE estimates of our model for the early-war recruiting regime (April 1861 – February 1863).[27]

The findings discussed in previous sections find confirmation in the maximum likelihood estimates. We estimate statistically significant and large positive effects, of a half-inch or more, for ages older than 18, for birth outside the Northeast, and for farmers relative to other occupations. Literate volunteers without disciplinary problems were taller than other soldiers, though these effects are smaller and, due to small sample sizes, not

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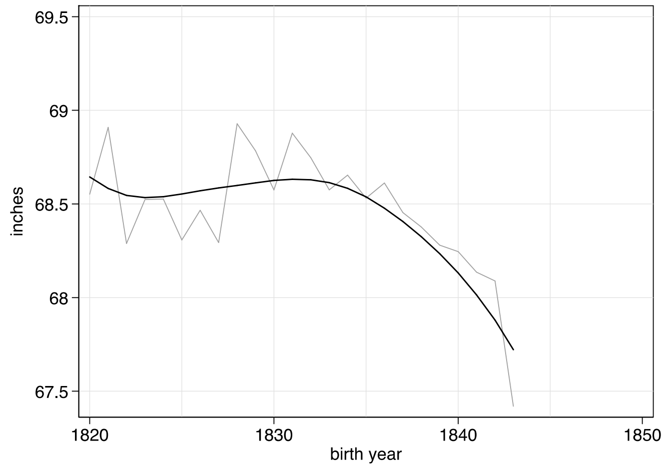
[26] If expected height in the population is a linear function of dummy variables, expected height in a truncated population (e.g. all heights 64” and above) is a nonlinear function of those variables.

[27] Heights in the early war sample used here were reported subject to a mixed rounding scheme, consistent with 35%, 37%, 13%, and 2% of observations being rounded to the nearest whole-, half-, quarter-, and eighth-inch, respectively. Following a rule of thumb developed in A’Hearn (2006), the truncation point in the likelihood function was set to 63.65”.

always significant.[28] The time trend is our primary concern. Figure 3.9 shows that men born in the 1820s, grew to statures just above five feet eight and a half inches on average. Small samples in individual years mean the year-to-year movements in the series are large, but the absence of any clear trend is obvious. From a point in the early 1830s, their final heights began to decrease, the cumulative decline reaching more than an inch by the early 1840s. This estimate, to repeat, refers to the population rather than just the military sample, and is highly statistically significant. 13 of 17 birth cohort effects before 1837 are significantly positive relative to the 1840 reference; all those after 1841 are significantly negative.

Fig. 3.9. New estimates of population mean heights



Note: Plotted are truncated maximum likelihood estimates of mean height from a regression of height on dummies for age at measurement, birth-year, birth-region, occupational group, enlistment status, literacy, and disciplinary record (Table A8). The estimating sample comprises native-born recruits aged 18-50 at measurement, with heights of at least 64 inches, enlisting before 1 March, 1863. Thin gray line: annual estimates summing the regression constant and relevant birth-year effect. The thicker, dark line is smoothed using locally weighted regression with a bandwidth of 0.8. The reference is a literate, volunteer, mid-Atlantic-born farmer, aged 22 or more, who faced no disciplinary action during service.

We can assess the trend decline in heights more easily if we re-estimate the model with five-year birth quinquennia beginning with 1820 replacing annual birth-cohort dummies. This yields the estimates in Table 3.1. Over the first three periods from 1820 to 1834, heights are essentially stagnant; though mean heights appear to drift gently upward, the differences are small and not statistically significant. The trend inversion of the 1830s emerges clearly. By 1835-39 heights have declined by a quarter-inch, and the estimate is

[28] The small number of draftees and substitutes in the sample (ca. 200, or about 1%) were subject to state-level conscription prior to the Enrollment Act, or re-enlisted as substitutes after a first enlistment as volunteers during the early part of the war.

highly statistically significant. The soldiers of this birth cohort were all 22 and older at the time of measurement, hence fully-grown. Decline continues at the same pace in the years that follow, falling another quarter-inch by the birth cohort of 1840-44. The continuing decline is also highly statistically significant.

Table 3.1. Maximum likelihood estimates of population birth cohort effects (inches)

period	*estimated effect*	*n*	*ages*
1820-24	0.15	685	37-44
1825-29	0.18**	1152	32-39
1830-34	0.26***	2032	27-34
1835-39	(*reference*)	4021	22-29
1840-44	-0.24***	6878	18-25

Note: estimating sample restricted to men enlisting under the early-war recruiting regime. Truncated maximum likelihood estimates of model in Table A8, with single-year birth-cohorts replaced by five-year groups. *** $p \leq 0.01$, $p \leq 0.05$

In sum, the antebellum puzzle of declining heights in a growing economy is not a statistical mirage induced by selection effects, nor the product of random sampling variability. It affected the entire population and not only military recruits.

4. Corroborating evidence

4.1 *Further evidence on heights*

The decline in height in the antebellum period is not unique among the Union Army soldiers. On the contrary, it has been found in samples from the West Point Military Academy, from the regular military, from the Ohio National Guard, from the revolutionary militias, from numerous prisons, from runaway slave advertisements, from Certificates of Freedom of African Americans (both men and women), from passports (both men and women), and from slave manifests. To be sure, they are mostly based on non-random samples from these diverse institutions but there are enough of them from various regions, occupations, and social groups to be able obtain a convincing view of the overall pattern of physical stature in the U.S. both longitudinally and cross-sectionally. These numerous samples enable us to gain at least ten different perspectives into the nutritional experience of the American society prior to the Civil War.

The selection processes into these ten sources were completely different from one another. We have records from the most unfortunates of American society, the slaves, and we have also archival records pertaining to elites who traveled the world for business and pleasure. It would be an unfathomable coincidence if all of the various selection processes associated with these sources would have all biased the samples in the same direction. Such a proposition would violate the principle of parsimony of "Occam's Razor", i.e., the strategy in scientific explanation to keep them as simple as possible. Besides, the Certificates of Freedom of free-born African Americans of Maryland and Virginia did not undergo any selection whatsoever insofar as they pertained to this whole sub-population inasmuch as they had to obtain these certificates as proof of their status as a sort of internal passport at the time (Komlos 1992). Bodenhorn seemingly overlooks the significance of his own work in which he himself showed that the height of free-born black men in Virginia declined by 0.4 inches and that of women by 0.8 inches (1999, p. 984). Thus, all these samples also confirm the main outlines of the Antebellum Puzzle.

In order to convince ourselves that the selection processes were inconsequential to the issue at hand consider, for example, that the certificates of freedom of those African Americans who were born as slaves and manumitted later in life pertain to those who were selected by their owners for manumission. What possible incentive would slave owners have to free taller slaves born in the early period and shorter ones later on at a time when slave prices were increasing rapidly and therefore manumission was associated with a substantial financial sacrifice in any event? Under such circumstances slaves were freed on humanitarian grounds and not on pecuniary ones, and it would be unwise to think that the slave owners would have made such decisions on the basis of physical stature. Many manumitted all their slaves, in which case there was no selection process at all; moreover, often manumission took place when their owners died so that its timing was inherently random.

Or consider the West Point Cadets. They also went through a selection process but what mattered there most were political connections with a congressman. That is a unique mechanism. It is simply implausible that such different mechanisms would produce uniform sampling biases.

Additionally, estimates based on these data sets reveal a coherent pattern in the way economic processes affected the physical growth of those who experienced the onset of modern economic growth as children or youth. The overarching pattern makes perfect economic sense: average heights declined at a time when agricultural productivity failed to keep pace with the rapid population growth, causing food prices to increase markedly (Craig 2016). Hence, income (and utility) could increase even as food consumption and height diminished among children and youth. There is no conundrum there.

After all, the US population expanded in this period by 21 million, or by a factor of 2.4, while urban population increased by a factor of 5. On account of the fact that the industrial labor force increased rapidly, the share of the labor force employed in agriculture declined from 71% to 56% during the course of the antebellum decades (Weiss, 1992, p. 22). In 1820 one agricultural worker produced enough food to feed about four persons but by 1870 one worker had to produce food to support 6 people and all that before substantial technological improvements took place. No wonder that food prices increased, inducing many consumers to substitute away from edibles and toward industrial products in their consumption bundle so that food consumption declined.[29]

Moreover, focusing on the increase in average income is misleading insofar as it masks the incontrovertible evidence that incomes became more unevenly distributed during those decades so that for a large segment of the population real incomes did not increase sufficiently to keep pace with the increases in food prices or the increases in urban rents (Komlos 1987, 1998). For instance, between 1830 and 1857 the New York City housing price index increased by some 50% which must have put a substantial dent in working class budgets, leaving them less money to spend on food, although it obviously did not affect the wealthy who owned their own houses (Margo 1996). Furthermore, these rent indexes have not yet been incorporated into most price indexes.

However, it is essential to note that not everyone experienced a decline in nutritional status in the antebellum era. As one would expect, those with sufficient income to afford to travel abroad were able maintain their food intake in spite of the hefty increases in food prices, and therefore did not experience a diminution in their physical stature at all (Sunder 2011, 2013). In other words, income was protective of height as one would expect. The height of those upper-class boys, girls, and women increased continuously, while the height of the wealthy men in 1860 was still at the high level of the 1820s birth cohorts. In addition, the height advantage of wealthy men relative to their commoner counterparts increased from 0.4 inches in 1830 to 1.2 inches by 1860 while the advantage of women passport applicants increased by 0.6 inches from 1.3 inches to 1.9 inches (Carson, 2011, p. 159; Sunder 2011, p. 169; 2013). This divergence between the height of the wealthy and

[29] This began to change during the era of Reconstruction when innovation in agricultural technology and their adoption made steady strides and refrigerated railroads cars began to connect markets in perishables.

that of the average men and women was indicative of the Kuznetsian rise in inequality at the beginning of modern economic growth.

The immunity of the wealthy to price increases was true even in populous towns such as New York and Boston where the adverse epidemiological environment would have put additional strain on the human biological system and where prices were above average. Yet, the height of the well-off did not decline at all. They were able to withstand those additional claims on their food intake, in spite of the price increases and in spite of the heavy disease incidence of those urban environments (Sunder 2011, 2013).

Hence, the trend in the height of passport applicants was an important confirmation of the theory that the shrinking of the population was truly a matter of incomes, their distribution, and food prices. Suddenly, the pieces of the puzzle began to fit together quite well and turned out to be not so mysterious after all. There was yet additional confirmation: the height of a sub-group of West Point Cadets whose fathers had middle-class occupations actually increased in the late 1830s just as the height of the general population was decreasing, confirming the finding that income provided immunity to the adverse effects of economic growth (Lang and Sunder, 2003). Their height in 1860 was the same as it was in the 1820s. There was no sign of decline among Harvard students either (Bowles 1932, p. 19). In fact, there was an uncanny similarity between the trends of the height of passport applicants and those of the middle class sub-group among the West Point cadets (Sunder 2013, p. 256). Their heights evolved perfectly parallel to one another in spite of the completely different selection process which generated the two samples. These results were like keystones in the explanatory arch of the Antebellum Puzzle.

In stark contrast to the wealthy, another group who maintained their stature was at the diametrically opposite end of the social pyramid; they were the most unfortunate of all: the slaves. The reason is that slave owners had a distinct economic incentive to maintain the productivity of their chattel and the only way they could accomplish that was to maintain their nutritional status (Margo and Steckel, 1982; Steckel, 1995; Komlos and Coclanis 1997; Komlos, 1998; Carson, 2009). On the basis of the trends in the prices of cotton and slaves one would expect that wealth-maximizing plantation owners would have even increased the nutritional status of their slaves in spite of the increase in food prices (Rees et al., 2003). After all, slave prices increased by some 60% in the antebellum decades and one would not expect slave owners to allow the nutritional status of such valuable possessions to deteriorate during a boom in cotton production with rising cotton prices. Consequently, plantation owners continued to provide an adequate amount of nutrients to their fettered workers so that they could work like slaves were expected to work; the profit motive dictated it. After all, their productivity was at stake and given the increasing value in the slaves' productivity on the new lands of the Deep South it made economic sense to maintain and perhaps even improve the slaves' nutritional status.

So, crucially, the distinction was not between whites and blacks insofar as the height of free blacks had a similar trend to that of whites (Komlos 1992; Bodenhorn 1999). Rather, it was evidently a distinction between free and unfree: slave heights did not respond to relative food prices, because they were not free to choose their consumption bundle. In other words, their nutritional status had a different dynamic, a different internal logic, as it depended on efficiency wage considerations (Komlos and Coclanis, 1997, p. 452; Rees, et al., 2003). In short, slaves were not integrated into a food market; hence, they were not exposed to the vagaries of food-price fluctuations. They were constrained to consume their allotment: and were not allowed to substitute manufactured goods for them.[30]

In addition to the wealthy and to the slaves, subsistence farmers were also immune to the food price increases, because food prices obviously did not affect them: they were not integrated into the market (Yoo, 2004). Hence, we find that the height of convicts in Tennessee did not decrease inasmuch as the farmers in the state remained self-sufficient in pork production to a considerable extent (Sunder 2004). Thus, the trends in physical stature among these groups confirms to the economic logic of the antebellum puzzle: only the height of those groups declined who were exposed to the increasing food prices and whose income was not increasing sufficiently to accommodate the rising food prices. Slaves were not affected; self-sufficient farmers were not affected; and the wealthy were not affected.

To be sure, for some time the argument was contemplated that the decline in height was due solely or primarily to the spread of diseases brought about by urbanization, the epidemics brought to this country by immigrants, and rapid population growth. However, that possibility wilted when it became quite clear that there were significant number of people whose heights did not decline at all even in the urban areas in spite of the substantial increases in the urban crude death rate (Sunder 2013). Diseases would not have discriminated to such an extent by social status. It seemed implausible that the rich would have immunity to infectious diseases if their incidence had truly increased and the

[30] "Free men who themselves chose their consumption bundle in the 1830s and 1840s responded to the changes in relative prices, whereas slaves who were not allowed to do so, did not" (Komlos 1996, p. 211).

epidemiological environment had deteriorated.[31] In addition, there was evidence that the crude death rate in New York State outside of New York City did not deteriorate at all (Haines 1998) whereas heights did diminish there and furthermore heights also declined in the South even though urbanization and immigration were limited there. So all in all there were too many inconsistencies with a disease explanation of the decline in heights to warrant serious further consideration.

4.2 *Corroborating evidence of food production and consumption*

Height data were not analyzed in isolation. The discovery of the decline in heights made it imperative to explore the trends in food consumption, the upshot of which was the realization that per capita protein and calorie intake of the population declined during the antebellum period. This issue was raised very early in the anthropometric research program: "the rapid growth of cities between 1820 and 1860 appears to have caused severe housing shortages, and thus possibly a sharp rise in the price of shelter… [which] could have led to a reduction in food consumption, particularly among the urban poor (Margo and Steckel, 1983, p. 173)."

A thorough dynamics of food consumption in these decades was first elucidated in Komlos (1987). This calorie accounting framework provided corroborating evidence for the decline in heights because it indicated that the U.S. population's per capita calorie and protein intake did decrease by about 10% between 1839 and 1849. Thus, there was a clear rationale for the heights of children and youth to decline. Moreover, insofar as inequality increased as well at the time (Kuznets, 1973; Williamson and Lindert 1980) the consumption of food also became more unequal and there were those whose calorie intake declined by multiples of the average.

This result was questioned initially by Gallman whose "Ptolemaic epicycle" was the conjecture that inventories of foodstuffs carried over from year to year were left out of the calculation (1996, p. 196). Such fluctuations in inventory must have been tiny, however, compared to total output so Gallman's critique did not take hold (Komlos 1996). Instead, over time the decline in calorie and protein intake during the antebellum decades emerged as the consensus view. For example, Haines et al. accepted the notion that "figures on agricultural production suggest that the quality and quantity of protein and calories in the average American diet deteriorated in the decades following 1830 (2003, pp. 383)." They

[31] To be sure, the wealthy would have had a higher nutritional status which would have given them some advantage against some diseases that were nutrition sensitive.

calculated a decline in calorie and protein consumption of 12% and 21% respectively, i.e., greater than those estimated by Komlos (Haines et al 2003, p. 396).

The most recent confirmation of Komlos's calculation of 1987 was that of Floud et al. (2011). Their independent recalculation of the agricultural data yields a decline of 9-14%, thereby confirming, in the main, Komlos' earlier estimates (Floud et al., 2011, p. 314; Komlos, 1987). Floud et al. conclude, "The estimates… indicate a considerable decline in diet after 1840; the 1840 level was not recovered until 1870. A large decline in per capita production of wheat, rye, pork, and beef accounts for this big deficit in American dietary history. The lack of nutrients was demonstrated by the soaring prices of those foodstuffs, another downside indicator of food consumption (2011, p. 316)".

Another confirmation of the food-consumption explanation of the decline in heights was the evidence that heights correlated positively with protein and calorie production in the county in which the recruits were born even after controlling for crude death rate, occupation, wealth, and access to transportation (Craig and Weiss. 1998, p. 199; Haines et al., 2003, p. 404). This implied that food prices did, in fact, matter to height, i.e., propinquity to nutrients lowered food prices which had a positive impact on the nutritional status of the local population.

However–and this was just as crucial–this relationship between height and food production in the county of birth did not hold for the black Union Army soldiers (Haines et al. 2003, 2011). In fact, for them the relationship was exactly the opposite: height correlated negatively with local production. This fit well into the framework elucidated above, on account of the fact that the logic of "efficiency wages" implied that slave food rations should not have been made only on the basis of food prices, but the value of slave production should also have been considered by the plantation owners. The less food produced locally the more valuable cotton was produced and the more important it was to provide protein as an "efficiency wage". In other words, the profit motive insulated the slaves from the deleterious effect of rising food prices (Rees et al., 2003).

And it is not only the mean calorie and protein intake that count. The distribution of nutrients must be considered as well, because of the increase in inequality (Steckel 1983). The reason is that there are diminishing returns to the consumption of nutrients and the income elasticity of demand for nutrients (calories, protein, micronutrients) declines with income. A plausible distribution of calorie intake suggests that among adult males the share of those whose food intake fell below adequate amounts for heavy work at a sustained level most probably increased substantially (Komlos 1996). A 10% decline in mean calorie consumption may not appear like a lot but it nonetheless most likely had a substantial impact on those at the lower tail of the income distribution. Hence, the estimated average decline in food intake does not reflect the full impact of the changes on the nutritional status and therefore on the height of most of the population.[32]

The increases in food prices both absolutely and relatively to manufactured products and the concomitant decline in food intake should not have been surprising given the extremely rapid growth in both population and urbanization and the decline in the share of the labor force in agriculture at a time when technical change in agriculture was still in its infancy. In other words, technological change and productivity growth in the agricultural sector did not keep pace with the growth of the population and per capita food intake declined. The share of the labor force engaged in the agricultural sector declined from 74% in 1800 to 56% in 1860 or by 18 percentage points. Given the slow pace of technical change in antebellum agriculture, it would have been virtually impossible to maintain the nutritional status of the population at pre-industrial levels under such rapid sectoral shifts. Indeed, one would have a major conundrum to explain if the calorie estimates had come out otherwise, and had indicated that per capita availability of nutrients did not decline. Floud et al confirm this view: "…the increase in agricultural productivity did not keep up with the rapid growth of the population and its food demands. (2011, p. 298)" These results provide crucial independent corroborating evidence for the decline in nutritional status and in heights.

Furthermore, there is a lot of fragmentary evidence supporting the conclusion that calorie and protein intake declined in these decades. For example, after 1840 ". . . the number of swine on Massachusetts farms fell off so sharply that by the 1855 census, swine are not even counted in 15 of the 31 towns" of Massachusetts (Rothenberg, 1979, 1981). Haines (1998) also documented a 70% decline in hog production and the 30% decline in cattle production in New York State between 1825 and 1860.[33] Cuff confirmed the decline in pork production at the national level (1992). In addition, as consumption shifted

[32] "Obviously, even a small change in average nutrient intake meant that an increasing proportion of the bottom segment of the income distribution was falling below a minimum threshold level of consumption that made the attainment of the heights of the 1820s increasingly difficult (Komlos 1996, p. 208)".

[33] These numbers do not even include the population of New York City insofar as it increased by a factor of eight during this period and would have shown an even more dramatic decline in livestock production on a per capita basis.

increasingly from rural to urban areas food products were transported longer distances which, in turn, meant that a significant share of the nutrients were lost in transit.

Furthermore, Margo improved the estimates of real wages by incorporating the cost of housing and found that the increase in wages was less uniform than hitherto thought. He estimated that the slower and sporadic growth of wages accounted for about half of the decline in heights (2000, pp. 4, 150-151). He also found that poverty rates rose substantially in the antebellum period: "poor relief increased by 76% during the 1850s" (Margo, 2000, p.152; Kiesling and Margo, 1997), and that unemployment increased during the periods 1839-42 and 1854-55 was documented by Goldin and Margo (1988). Although this might appear temporary, children and youth whose father became unemployed during one of the crucial biological growth phases—in uterus, as a baby, or during the adolescent growth spurt—could have been affected permanently. That is one of the advantages of using anthropometric measures: they are sensitive to such temporary setbacks. Margo concludes that "Declines in real wages over subperiods may help explain certain declines in nutritional status and were also instrumental in the rise in pauperism in the 1850s (2000, p. 4)." In other words, variability of income is an independent causal factor in the decline in heights (Komlos 1998).

Moreover, the recession of 1837 was accompanied by labor unrest and strikes: "Nominal wages lagged behind when prices soared in the mid-1830s and early 1850s, contributing to a wave of strikes and labor agitation" (Margo and Villaflor, 1987, p. 889). Importantly, nominal wages stagnated throughout the antebellum period until 1853 when they rose slightly. This meant that real wage fluctuations depended a lot on food prices. While real wages might increase, they did so only to the extent that the price of manufacturing goods decreased, but insofar as food prices were increasing it was difficult for the average worker to maintain food intake at the level of the 1820s with constant nominal wages (Margo and Villaflor, 1987, p. 880). As a consequence, the value of nominal wages in terms of food declined throughout the period for ordinary workers. The wages of artisans purchased 13% less grain in the 1850s compared to the 1820s (Komlos 1998, p. 787).

Researchers usually focus on urban prices and they did increase markedly: in Philadelphia, for instance, food prices relative to manufactured goods rose by 37% between the 1820s and 1850s (Bezanson et al, 1936). However, farm-gate prices were much more relevant, because even in 1860 the population was still 80% rural. So the fact that the price of grain increased relative to that of cloth by no less than 173% in Vermont is much more indicative of the power of price movements in this period to induce consumers to substitute away from food products and toward non-edibles (Adams 1939).

In sum, anthropometricians did not analyze heights in isolation. Rather, much corroborating evidence on nutritional status was brought to bear in order to understand the economic and demographic processes of the epoch and thereby to verify that the various developments accompanying the onset of modern economic growth including exponential increase in urbanization, rapid population growth, substantial relative and absolute price movements, increase in inequality, acceleration in industrial output, the declining share of the labor force in agriculture, increased variance of income, and sluggish growth in agricultural productivity all fit together in a coherent economic kaleidoscope.

That mass of evidence from disparate sources should suffice to convince the staunchest of sceptics, but there is more. We also came across information on the weight of West Point cadets in the period and they were found to have extremely low BMI values although they were by no means from the poorer segments of the society.[34] The average weight of 20-year-old cadets was c. 131 pounds (60 kg) with a BMI value of 20.4 (Cuff 1993). This implies that nutritional status was extremely low: "evidence on the weight of the cadets contradicts the notion that they had unlimited access to food supplies. In fact, they were quite underweight: many weighed between 100 and 120 pounds… the weight of the cadets is the only incontrovertible evidence on the contemporaneous nutritional intake of the cadets…" (Komlos 1987, p. 919). More recently Carson found that the BMI values of convicts, both males and females, were declining during the antebellum decades corroborating the diminution in nutritional intake in this period (2015; 2016). Hence, these findings add a decisive piece to the solution of the Antebellum Puzzle, because this solid evidence contradicted the notion that Americans had unlimited access to food relative to the demands of the epidemiological environment and of the physical exertion of daily life imposed by the technology of the time.

4.3 *Additional research on selection*

Ariel Zimran devotes a chapter of his forthcoming dissertation to estimating the selection effect in the Union Army during the Civil War. He finds that after accounting for a possible selection bias heights declined between the birth cohorts of 1830 and 1846 by between 0.7 and 0.85 inches (depending on the specification). This is practically identical

[34] The birth weight of poor children in Philadelphia prior to the Civil War was in the 10^{th}-25^{th} percentile of modern standards (Goldin and Margo 1988, p. 10). This is also indicative of severe nutritional constraints of the time.

to A'Hearn's earlier estimated decline of 0.8 inches from the 1820s to the end of the 1840s (1998, p. 53) as well as to our current estimate of a decline of 0.7 inches. In other words, Zimran's estimate solidly confirms the existence of the Antebellum Puzzle as well as the actual size of the decline, thereby completely vitiating Bodenhorn, Guinnane, and Mroz's critique.[35] It would be difficult to imagine a better confirmation: this implies that selection on heights was not the cause of the decline in heights. In other words, Zimran's research reveals that the Bodenhorn, Guinnane, and Mroz critique is, in actuality, much ado about nothing.

5. *Sundry corrections*

a) There are also a number of incorrect claims in the Bodenhorn, Guinnane, and Mroz paper: for instance, they attribute to anthropometricians (without citation) the suggestion that „a society can embark on a path of long-run economic growth only if it witnesses improvements in each generation's physical wellbeing" (p. 2). We know of nobody who has made such a claim. It should be obvious that laborers who do not receive the optimal amount of nutrients can nonetheless produce sufficient profits to lead to capital accumulation which in turn can lead to long-run economic growth. One only has to consider the emaciated bodies in Zola's *Germinal*, or the hunger and misery documented in Engels' *Condition of the Working Class in England* to realize that an economy can most certainly embark on modern economic growth without an improvement in physical wellbeing for an extended period of time. This is especially the case if the stock of biological human capital was high at the onset of modern economic growth as was the case in both England and the United States (Komlos, 1990). In England it took about a century

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35 Bodenhorn, Guinnane, and Mroz's characterization of Zimran's conclusion is misleading: "The selection biases he uncovers with this approach are not severe enough to completely overturn the apparent downward trend in heights over this time period" (2015). Not only does it not "completely" overturn it; it does not modify it one iota. They continue: "Zimran's (2105) study clearly indicates that there are potentially severe sample selection issues." Potentially, yes, but Zimran finds the issue of actual importance only for his newly-collected data from the Regular Army, which he uses to estimate heights for birth years extending beyond the mid-1840s, right up to 1860. About declining heights in the 1830s and '40s, he writes that "it is possible to conclude from these results that the sample-selection bias suggested by Bodenhorn, Guinnane, and Mroz (2013, 2014) does not explain the industrialization puzzle, and therefore that it is the result of some actual change in heights in the population" (2015, p. 34). Zimran continues: "The industrialization puzzle is found to be robust to corrections for sample-selection bias, contrary to the arguments of Bodenhorn, Guinnane, and Mroz (2015, p. 37)… and therefore is not an artifact of sample-selection bias. (2015, pp. 1, 5)"

for heights to regain their pre-industrial levels while in the US it took a bit shorter: about seven decades (Zehetmayer, 2011).

b) Bodenhorn, Guinnane, and Mroz suggest that "The antebellum puzzle is all the more puzzling because, among the early industrializers, only England, Sweden and Austria-Hungary appear to have experienced a puzzle." This is not quite the right way to frame the issue. A country did not have to be industrializing rapidly in order to experience a nutritional downturn. It sufficed that its markets were integrated with that of the industrializing one in order for nutritional status to decline insofar as the increase in the price of its agricultural products would send ripples through to the connected markets. So the onset of the Industrial Revolution in Great Britain had repercussions on nutritional status throughout the Continent and as far away as Russia. Of course, the onset of the demographic revolution simultaneously everywhere on the Continent at around the middle of the 18th century and the increase in urbanization and population density exacerbated the nutritional downturn. Hence, heights declined at the same time all over Europe in the second half of the 18th century or in the middle of the 19th century including in Saxony (Cinnirella, 2008a, p. 245), Scotland (Cinnirella, 2008b, p. 344), Ireland (Komlos 1993a, p. 136), England (Komlos and Küchenhoff, 2012), Bavaria (Baten 1996), Germany (Coppola, 2009, p. 89), Lombardy (A'Hearn, 2003, p. 371; 2006), The Netherlands (Drukker and Tassenaar, 1997), Russia (Mironov and A'Hearn, 2008.), the Papal States (Coppola, 2013), and France (Komlos et al., 2003). There are no exceptions. They all faced the same price trends and real wages declined everywhere.

And in several of these cases, there are multiple samples including soldiers and convicts (Komlos 2004; 1993b), and in some cases--including Bavaria (Baten and Murray 2000, p. 364),— there is additional evidence that women's heights also conformed to the main model. The decline in height can be also observed in conscript samples in which every young man was measured (Lantzsch and Schuster, 2009, p. 52).

c) Bodenhorn, Guinnane, and Mroz suggest that "While a 0.75 cm decline is nontrivial, it is not consistent with a mid-century nutritional crisis." No one would be silly enough to talk about a nutritional crisis in such a land- and resource-abundant country as the USA. Rather, we always talked about a diminution in nutritional status or a decline in calorie and protein intake of around 10%, as mentioned above.

d) In a probit regression analysis predicting a height decline across many different samples, Bodenhorn, Guinnane, and Mroz find it more likely that heights declined in volunteer armies. A major problem with their specification, however, is that it is plagued with omitted-variable bias, insofar as they do not control for many crucial variables that are pertinent to the analysis. So they conflate Colombian driver license applicants in the 20th century with British indentured servants of the 18th century or American slaves of the 19th century. Analyzing such a heterogeneous sample encompassing centuries and pertaining to several continents, they would have had to control for such independent variables as social status, region of the globe, epoch, technological change, nutrient prices, youth, as well as for national characteristics such as the rate of urbanization in order not to be overwhelmed by omitted variable biases.

They would have had to control for time with dummy variables instead of a continuous logarithmic function that is unable to capture crucial regime switches. These omissions and commissions imply that their regression is misspecified and vitiates their inference, because volunteer armies tended to predominate primarily in the early period when there were two periods with nutritional downturns and heights tended to decline in the 18th and the first half of the 19th centuries. By the second half of the 19th century there were hardly any more declines in height in the developed part of the world, inasmuch as the food supply chain was solved with a rise in agricultural productivity and diminution of transport costs that included the discovery of refrigeration (Craig et al., 2004). In other words, it is crucial that the decline in heights in the antebellum period is examined in the context of the technological and demographic developments of the period which put their stamp on the dynamics of the economic system. The antebellum period is unique in that it witnessed a conjuncture of demographic, economic and technological processes that produced an anomaly and therefore has to be analysed on its own terms and in its own context.

e) Furthermore, Bodenhorn, Guinnane, and Mroz's meta-analysis of a number of samples devoted to the Antebellum Puzzle calculates the average height change (p. 12 and Table 1, column 5). The problem with what they call an "unsophisticated" approach is that they fail to recognize that these samples ought not be intermingled, because there is too much heterogeneity among them:

1) some of the studies cited were of a preliminary nature with a small number of observations and their results were superseded with subsequent studies. Thus, Margo and Steckel's (1983) early analysis of the Union Army sample had merely 1,080 observations in their urban regression. It is unacceptable to consider their results on an equal footing with, for example, Cuff's (2005) analysis of Pennsylvanian heights with 22,000

observations. The current Union Army sample has 23,662 valid observations (Fogel et al., 1990). Pilot studies of sub-samples should no longer be considered as meaningful.

2) the diminution in nutritional status ended shortly after the Civil War,--except for the ex-slaves,--as agriculture expanded and food prices declined in line with the technological changes of the period so that by 1879 even the lower bound per capita calorie and protein consumption exceeded the antebellum peak (Komlos, 1987, Table 8). This implies that these samples should be analyzed in context and the post-Civil War samples should not be intermingled with the earlier samples if one wants to understand the trend in heights. These were entirely different epochs from an economic perspective. The antebellum period witnessed the onset of modern economic growth with limited agricultural innovation while during the post-Civil War period technological change was becoming widespread in the agricultural sector with the consequence that it was becoming much more productive. If one conflates these two periods one loses sight of these salient differences and it becomes impossible to understand the dynamical economic processes and their nutritional concomitants.

3) Slave samples should also not be included in such a calculation, because slaves were not part of the market economy, were not responsible for their own nutrition, were not allowed to substitute industrial products for edibles, and consequently were subject to a very different dynamic of nutritional status than the free population.[36] Thus, the height of slave men did not decline during the antebellum period at all and in some samples even tended to increase (Komlos and Coclanis 1997; Steckel 1995).

4) Middle class samples are also not pertinent to the issue at hand, because they were the beneficiaries of economic growth. Their income increased sufficiently to counteract the rise in nutrient prices.

Hence, for these reasons many samples do not belong in a meta-analysis of the trend in the physical stature of the free population in the antebellum period (Table 5.1). These objections eliminate ten of the samples used by Bodenhorn, Guinnane, and Mroz (Table 1). The mean decline among the remaining samples is 1.16% or 2 cm (0.8 inches)

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[36] "In contrast to free men, slaves were not allowed to choose their consumption bundle themselves, but depended, in the main, on their masters' food allotments. They were assets, capitalized labor, as it were, whose productivity and value would decline if their nutritional status diminished significantly. Ironic as it may appear, the most degraded of American workers were, therefore, isolated from the market forces associated with the onset of modern economic growth, which affected adversely the biological standard of living of the free population" (Komlos, 1998).

which is about three times their estimate and almost identical to the estimated declines reported above.

Table 5.1 Samples considered by Bodenhorn, Guinnane, and Mroz in order to test the relationship between recruiting practices and the decline in heights which are either not pertinent to the Antebellum Puzzle or have been superseded by larger data sets

	Authors	Pub year	period	Sample	Reason for exlusion
1	Margo & Steckel	1982	1790s-1830s	Slaves	Slaves
2	Margo & Steckel	1982	1810-1830s	Black Recruits	ex-slaves intermingled
3	Margo & Steckel	1983	1810-1830s	Union Army	preliminary
4	Komlos	1996	1820s-1870s	West Point	Middle Class
5	Coclanis & Komlos	1997	1860s-1880s	Citadel	Post-Civil War era
6	A'Hearn	1998	1810s-1830s	Union Army	misreading
7	Komlos	1998	1810s-1840s	Union Army	Black Recruits
8	Bodenhorn	1999	1800s-1830s	Manumitted	ex-slaves intermingled
9	Hiermeyer	2010	1860s-1880s	West Point	Post-Civil War era
10	Sunder	2004	1830s-1850s	Prisoners	Tennessee self-sufficient

6. Conclusion

Fogel et al. reported in 1979 and several times thereafter that the height of Union Army soldiers declined in the antebellum decades. This was surprising in an economy that was growing robustly: real income was 60% higher in 1860 than it was in 1820 (Weiss 1992, p. 27). Therefore, the finding unleashed a flurry of research among anthropometric historians in order to learn how widespread the phenomenon actually was and to understand the economic processes that gave rise to the diminution in nutritional status at a time of prosperity. No archives were left untouched and dozens of additional data sets were analyzed which all pointed in the same direction: nutritional status declined among the majority of the U.S. population. A subsequent examination of food production and consumption records corroborated this evidence. It was also reassuring that those who were exempt from a diminution in nutritional status were those who were not affected by the increase in food prices for one reason or another: they were sufficiently wealthy to be able to cope with the surge in food prices, they were not free to choose their consumption bundle, or were isolated from market processes.

Now come Bodenhorn, Guinnane, and Mroz (2015) to question this thesis by suggesting that the decline in the height of soldiers is merely the consequence of selection into military service: shorter men entered the military over time as business conditions improved and the more productive taller men chose to work in the private sector instead of the military. “Improvements in civilian labor markets will lead to a shorter army,” they suggest. So the height of soldiers is not representative of the population at large. They claim that the height of soldiers declined but that of the population may not have.

However, the oversight in their assertion is that they failed to provide any evidence at all that labor markets improved in the civilian sector. This was quite an omission for during the course of the Civil War just the opposite happened, army heights decreased while military compensation *increased* --dramatically so—relative to civilian earnings. As a matter of fact real wages in the civilian sector declined relative to military pay by some 39% to 66% during the course of the war. Hence, the effect of selection would have been exactly the opposite of their prediction.[37] On account of pecuniary considerations, i.e., if wage differentials had made a difference at all to recruitment, the military should have been more attractive to taller men over time and the height of the soldiers should have increased.

In contrast to their assertion, we have shown that the decision to enter the military was more a question of patriotism than of pecuniary considerations.[38] At the beginning of the conflict patriotic fervor led many middle-class men to enlist so that initially the soldiers were a perfectly representative sample of the population of all American men but as the fighting dragged on a larger share of the soldiers came from the lower social strata who were shorter even controlling for occupation. As a consequence, the height of enlisted men declined as the war progressed. However, as we demonstrate, within each enlistment period analyzed separately the trend in height was uniformly negative. That is to say, those who were born in the late 1830s and 1840s were shorter than those who were born in the 1820s and early 1830s. This was true for those who enlisted early in the war as well as those who enlisted late in the war even though those who enlisted in 1861 were taller than those who enlisted in 1865. This is even true if we restrict some of the regressions to enlistment windows as short as 90 days—a period too short for possible incentives of civilian pay to have changed appreciably— and the results were the same nonetheless. Heights declined

[37] Similarly, during the Second Industrial Revolution after the 1870s, military heights remained unchanged and then began to increase among the birth cohorts of the 1880s at a time when opportunities in civilian employment were plentiful (Zehetmayer, 2011). Their model would predict that with such demand for labor in the industrial sector taller men would choose civilian employment and thus military heights should fall. So their model is contradicted by the evidence also in the subsequent epoch. So their hypothesis must be rejected. Civilian wages played a negligible role in the height trends observed.

[38] Goldin and Lewis show that the risk premium was much less than the ex-post human capital loss. In other words, the share of wages of the recruits that served as a premium for the risk of dying or being wounded was “slight”. They “infer either that soldiers underestimated the probabilities of death and injury or that patriotic duty was a sufficient incentive” (Goldin and Lewis, 1975, p. 304).

consistently and by about the same amount. This implies that within each social cross-section of the population nutritional status was declining with successive birth cohorts.

We also replicated the regressions of Bodenhorn, Guinnane, and Mroz and found two mistakes that, when corrected, overturned their assertion that heights remained unchanged in the antebellum decades. Once we eliminated foreign-born soldiers and controlled for the minimum height requirement their finding was reversed and heights did, indeed, decline (Figure 3.1). Our analysis went further, slicing the data in various ways, by examining the trends within each enlistment year separately and by analyzing draftees, substitutes, and volunteers separately. We used maximum likelihood regression analysis, where appropriate, in addition to OLS. The results were robust: heights declined and declined and declined no matter how we analyzed the data. So our conclusions rest on an extensive evidential basis: there cannot be an iota of doubt that the diminution in height reflects the actual nutritional experiences of the population who lived through that momentous epoch of economic transformation.

Furthermore, several estimates, including that of Sokoloff and Villaflor, suggest that American men in the 18th century were about 68.2 inches tall (1982, Table 2). However, estimated heights in the 1870s based on a national sample of the regular army were closer to 67.2 inches (Zehetmayer 2011 Table 2). Thus, heights must have decreased sometime between the 18th and the second half of the 19th century. The Union Army data just enables us to pinpoint when that decline occurred. Our estimate of the height of Northern farmers born in the 1820s is about 68.6 inches which is reasonably close to heights in the 18th century (table 8A). Similarly, our estimate for 1842 of about 67.9 inches in 1842 dovetails pretty well with the national estimate of 67.5 inches between 1847 and 1854 based on a different sample of the regular army (Zehetmayer 2011 Table 2).[39] Hence, of the 0.7 inch decline between the 18th and 19th centuries, our estimate suggests that all of it was obtained in the antebellum period. This is practically identical to a recent estimate by Ariel Zimran who estimates the decline as 0.7-0.85 inches even after accounting for possible selection biases.

We have demonstrated that the "antebellum puzzle" is not such a conundrum after all. The main culprit responsible for the decline in nutritional status was the confluence of processes which reinforced each other and brought about a decline in food consumption of the average person. Floud et al. conclude recently that "…food output did not keep pace

[39] The South is excluded from this average, which decreases the average by about 0.1 inches.

with the demands of the urban-industrial sectors whose population increased approximately ten times during the first half of the nineteenth century…. Per capita crop consumption may have declined throughout the antebellum period. Excess demand had increased grain prices by 1860, and the change in food availability contributed to the decline in the population's nutritional status in the first half of the nineteenth century (2011, pp. 306, 308.).” This assertion is practically identical to Komlos' inferences of a quarter century earlier (1987).

Of course, mean heights would decline at a time when food consumption was also declining regardless of growth in GDP. It would be strange if they did not. In other words, there has been excessive emphasis on GDP growth as the sole indicator of living standards as Stiglitz et al. (2010) also argue in the modern context. In contrast, the anthropometric evidence emphasizes that a rising GDP was compatible with a decline in nutritional status of children and youth who had no agency to determine their own destiny.[40] Hence, economic growth was by no means a Pareto-optimal process. Instead, there were gainers and losers. This is also a new insight into the dynamics of economic development in the antebellum period worthy of note.

Actually, the pieces of the puzzle fit together quite neatly: “during the early stages of modern economic growth, progress was not uniform in all dimensions of human existence. For the common man, the standard of living as conventionally conceived diverged from the other standards of biological well-being. The human organism did not thrive as well in its newly created socioeconomic environment as one might be led to believe on the basis of purchasing power at the aggregate level.” “Thus, anthropometric history gives us a more nuanced view of the welfare of the American population living through the rapid structural changes of the antebellum years (Komlos 1996, p. 212)”. In brief, we conclude that there cannot be a shadow of a doubt that a substantial portion of the children and youth who experienced the onset of modern economic growth were not as well-nourished as their parents and grandparents.

The lesson is that “the nutritional status of a population can decline even during prosperous times during momentous economic changes such as the onset of modern economic growth, while the economy adjusts to sectoral shifts in production (Komlos 1987, p. 898)”. So it should be apparent that not all developments associated with the early stages of economic development were favorable to welfare. In other words, the most parsimonious explanation of the Antebellum Puzzle is in terms of endogenous economic

[40] Methodological individualism is extremely concerned about agency, but those who were hurt by economic growth had no agency at all and that is worth emphasizing.

forces that were unleashed by industrialization, urbanization, and the demographic transition. The increased income inequality, the increased variance of income, the rapid rate of urbanization, and the increase in the absolute and relative price of nutrients, all impinged on the biological standard of living of the common man, a rise in average incomes notwithstanding. As Haines, Craig, and Weiss put it: "It seems that the growing prosperity of the United States in the antebellum period was partly purchased at a price of some deterioration of the biological standard of living (2003, p. 409)."

Let us remind ourselves, however, that estimating the trend in height is not the main issue for the understanding of what it must have been like to experience the onset of modern economic growth. Height is not a good in and of itself and therefore we should not be particularly concerned with that phenomenon for its own sake. However, height is a robust proxy variable for nutritional status of children and youth—exactly the groups who are usually left out of consideration in conventional measures of welfare[41]—and once we discovered that heights declined for most of the population we began to study and learn more about the nutritional history of the period, discovering that calorie and protein intake did actually decline during these momentous years, as numerous studies have since confirmed. And that is the critical issue.

Thus, in some sense the discussion of the trend in heights ought not be the main focus. Rather, the onset of modern economic growth brought about changes in the diet that became less nutritious and these hitherto hidden negative concomitants of growth are important to recognize for our understanding of the dynamics of economic development in that period. Economic growth had some hidden negative externalities that were born by children and youth who were innocent bystanders. And that contribution of anthropometric history would remain even if Bodernhorn, Guinnane, and Mroz were right in their assertion that the trend in physical stature of the population has not been estimated properly. They're not, but if they were, we would have another conundrum to explain, namely, why heights did not decline at a time when the food intake of the population did, in fact, decline. So the selection of recruits into the Union Army is a minor issue as far as our understanding of the dynamics of the transition to modern economic growth is concerned. Hence, Bodernhorn, Guinnane, and Mroz's critique is nothing more than a tempest in a teapot: the nutritional status of the U.S. population did, in fact, decline at the onset of modern economic growth

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[41] These age groups are left out of conventional analysis, inasmuch as monetary measures pertain exclusively to adults and not to children and youth who are not employed. That is another major distinction between conventional and anthropometric perspectives of welfare.

in spite of rising average incomes. Progress was not invariably uniform in all dimensions of human experience. And that is worth a footnote in new perspectives on economic development, Ptolemaic detractors notwithstanding.

References

Adams, T. M. 1939. "Prices Paid by Farmers for Goods and Services and Received by Them for Farm Products, 1790-1871." University of Vermont and State Agricultural College, Vermont Agricultural Experiment Station, February.

A'Hearn, Brian. 1998. "The Antebellum Puzzle Revisited: A New Look at the Physical Stature of Union Army Recruits during the Civil War," in John Komlos and Joerg Baten, eds., *The Biological Standard of Living in Comparative Perspectives* (Stuttgart: Franz Steiner Verlag), pp. 250-267.

A'Hearn, Brian. 2003. "Anthropometric Evidence on Living Standards in Northern Italy, 1730-1860," *The Journal of Economic History*, 63, 2:351-381.

A'Hearn, Brian. 2004. "A restricted maximum likelihood estimator for truncated height sample," *Economics and Human Biology* 2:5-19.

A'Hearn, Brian. 2006. "Remapping Italy's Path to the 19th Century: Anthropometric Signposts," *Journal of European Economic History*, 35, 2:349-392.

Balakrishnan, N. and C-D. Lai. 2009. *Continuous Bivariate Distributions*. New York: Springer.

Baten, Jörg, 1996. "Der Einfluß von regionalen Wirtschaftsstrukturen auf den biologischen Lebensstandard. Eine anthropometrische Studie zur bayerischen Wirtschaftsgeschichte im frühen 19. Jahrhundert," *Vierteljahresschrift für Sozial- und Wirtschaftsgeschichte* 83, 2:180-213.

Baten, Jörg, 2015. "Strategies to cope with potential labor market bias and other selectivities in height research," Working Paper, University of Tuebingen, August.

Baten, Jörg, and Murray, John. 2000. "Heights of Men and Women in 19th-Century Bavaria: Economic, Nutritional, and Disease Influences," Explorations in Economic History, 37:351-369.

Baxter, Jedediah H. 1875. *Statistics, Medical and Anthropological, of the Provost-Marshal-General's Bureau, Derived from Records of the Examination for Military Service in the Armies of the United States During the Late War of the Rebellion of Over a Million Recruits, Drafted Men, Substitutes, and Enrolled Men*. Washington, D.C., Government Printing Office.

Bezanson, Anne, Robert D. Gray, and Miriam Hussey. 1936. *Wholesale Prices in Philadelphia 1780-1861.* Philadelphia: University of Pennsylvania Press.

Bodenhorn, Howard. 1999. "A Troublesome Caste: Height and Nutrition of Antebellum Virginia's Rural Free Blacks," *The Journal of Economic History* 59, 4:972-996.

Bodenhorn, Howard, Timothy Guinnane, and Thomas Mroz. 2015. "Sample-Selection Biases and the "Industrialization Puzzle," NBER Working Paper no. 21249, June.

Bowles, Gordon T. 1932. *New Types of Old Americans at Harvard and at Eastern Women's Colleges,* Cambridge, Mass.

Carson, Scott A. 2009. "African-American and White Inequality in the Nineteenth Century American South: A Biological Comparison," *Journal of Population Economics* 22:739-755.

Carson, Scott A. 2011. "Height of female Americans in the 19th century and the antebellum puzzle," *Economics and Human Biology* 9, 2:157-164.

Carson, Scott, A. 2015. "A Weighty Issue: Diminished 19th Century Net Nutrition among the US Working Class," *Demography,* 52:945-966.

Carson, Scott, A. 2016. "Body Mass Index through Time: Explanations, Evidence, and Future Directions," in Komlos, John and Inas Kelly (eds.), *Handbook of Economics and Human Biology*, Oxford University Press, forthcoming.

Carter, Susan, Scott S. Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright (eds.). 2006. *The Historical Statistics of the United States. Millennial Edition*, Cambridge: Cambridge University Press.

Case, Anne and Paxson, Christina, 2008. "Stature and Status: Height, Ability, and Labor Market Outcomes," *Journal of Political Economy* 116, 3:499-532.

Cinnirella, Francesco, 2008a. "On the road to industrialization: nutritional status in Saxony, 1690-1850," *Cliometrica* 2: 229-257.

Cinnirella, Francesco, 2008b. "Optimists or pessimists? A reconsideration of nutritional status in Britain, 1740-1865," *European Review of Economic History,* 12:325-354.

Coppola, Michela, 2009. "The biological standard of living in Germany before the Kaiserreich, 1815-1840: insights from English army data," *European Review of Economic History* 14:71-109.

Coppola, Michela, 2013. "The biological standard of living and mortality in Central Italy at the beginning of the 19th century," *Economics and Human Biology* 11, 4:453-464.

Craig, Lee A. 2005. Review of *The Hidden Cost of Economic Development: The Biological Standard of Living in Antebellum Pennsylvania,* by Timothy Cuff. *EH.net* , November 13, 2005, Book Review, http://eh.net/book_reviews/hidden-cost-economic-development-biological-standard-living-antebellum-pennsylvania accessed January 30, 2012.

Craig, Lee. 2016. “Antebellum Puzzle: The Decline in Heights at the Onset of Modern Economic Growth,” in Komlos, John and Inas Kelly (eds.), *Handbook of Economics and Human Biology*, Oxford University Press, forthcoming.

Craig, Lee, Goodwin, Barry, and Thomas Grennes. 2004. “The Effect of Mechanical Refrigeration on Nutrition in the United States,” *Social Science History*, 28, 2: 325-336.

Craig, Lee A. and Thomas Weiss. 1998. “Nutritional Status and Agricultural Surpluses in the Antebellum United States,” in John Komlos and Joerg Baten, eds., *The Biological Standard of Living in Comparative Perspectives,* Stuttgart: Franz Steiner Verlag, pp. 190–207.

Cuff, Timothy. 1992. “A Weighty Issue Revisited: New Evidence on Commercial Swine Weights and Pork Production in Mid-Nineteenth Century America,” *Agricultural History* 66, 4:55–74.

Cuff, Timothy. 1993. “The Body Mass Index Values of Mid-Nineteenth-Century West Point Cadets: A Theoretical Application of Waaler's Curves to a Historical Population,” *Historical Methods* 26, 4:171-182.

Cuff, Timothy. 2005. *The Hidden Cost of Economic Development: The Biological Standard of Living in Antebellum Pennsylvania*. Aldershot, UK: Ashgate Publishing.

David, Paul A. and Peter Solar. 1977. “A Bicentenary Contribution to the History of the Cost of Living in America,” *Research in Economic History* 2:1–80.

DeCanio, Stephen and Joel Mokyr. 1977. “Inflation and the Wage Lag during the American Civil War,” *Explorations in Economic History* 14:311-336.

Drukker, Jan W., and Vincent Tassenaar. 1997. "Paradoxes of Modernization and Material Well-Being in the Netherlands during the Nineteenth Century," in Richard H. Steckel and Roderick Floud (eds.), *Health and Welfare during Industrialization,* Chicago: The University of Chicago Press, pp. 331-78.

Floud, Roderick, Robert W. Fogel, Bernard Harris, and S.C . Hong. 2011. *The Changing Body. Health, Nutrition, and Human Development in the Western World since 1700.* New York: Cambridge University Press.

Fogel, Robert W., Stanley L. Engerman, Roderick Floud, Richard Steckel, T. James Trussell, Kenneth W. Wachter, Robert Margo, Kenneth L. Sokoloff, and Georgia C.

Villaflor. 1979. “The Economic and Demographic Significance of Secular Changes in Human Stature: The U.S. 1750-1960,” NBER Working Paper, April.

Fogel, Robert W., Stanley L. Engerman, Clayne Pope, and Larry Wimmer. 1990. Union Army Recruits in White Regimens in the United States, 1861-1865 [Computer file]. (ICPSR 9425-v2). Chicago: University of Chicago, Center for Population Economics [producer], Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor].

Fogel, Robert W., and Richard H. Steckel. 1995. Union Army Rejected Recruits in the United States, 1861-1865. ICPSR 9428-v1. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor].

Gallman, Robert E. 1996. “Dietary Change in Antebellum America,” *The Journal of Economic History* 56, 1:193-201.

Goldin, Claudia and Robert A. Margo, 1988. “The Poor at Birth: Infant Auxology and Mortality at Philadelphia’s Almshouse Hospital, 1848-1873,” NBER Working Paper no. 2525.

Goldin, Claudia D. and Frank D. Lewis, 1975. “The Economic Cost of the American Civil War: Estimates and Implications,” *The Journal of Economic History*, 35, 2:299-326.

Gould, Benjamin A. 1869. *Investigations in the Military and Anthropological Statistics of American Soldiers.* Cambridge, Mass.

Haines, Michael R. 1998. “Health, Height, Nutrition, and Mortality: Evidence on the ‘Antebellum Puzzle’ from Union Army Recruits for New York State and the United States,” in John Komlos and Joerg Baten, eds., *The Biological Standard of Living in Comparative Perspectives.* Stuttgart: Franz Steiner Verlag, pp. 155-180.

Haines, Michael R., Craig, Lee A., and Thomas Weiss, 2003. “The Short and the Dead: Nutrition, Mortality, and the ‘Antebellum Puzzle’ in the United States” *The Journal of Economic History* 63, 2:382-413.

Haines, Michael R., Craig, Lee A., and Thomas Weiss, 2011. “Did African Americans experience the ‘Antebellum Puzzle’? Evidence from the United States Colored Troops during the Civil War,” *Economics and Human Biology* 9: 45-55.

Heintel, Markus, and Joerg Baten, 1998. “Smallpox and nutritional status in England, 1770-1873: on the difficulties of estimating historical heights,” *Economic History Review* LI, 2: 360-371.

Hiermeyer, Martin. 2010. “The height and BMI values of West Point Cadets after the Civil War,” *Economics and Human Biology* 8, 1:127-133.

Horrace, William, C. 2015. “Moments of the truncated normal distribution,” *Journal of Productivity Analysis*, 43: 133-138.

Kiesling, Lynne and Margo, Robert. 1997. “Explaining the Rise in Antebellum Pauperism, 1850-1869: New Evidence,” *The Quarterly Review of Economics and Finance*, 37, 2:405-417.

Komlos, John. 1987. “The Height and Weight of West Point Cadets: Dietary Change in Antebellum America” *The Journal of Economic History* 47, 4:897-927.

Komlos, John. 1990. "Nutrition, Population Growth and the Industrial Revolution in England," *Social Science History* 14: 69-91.

Komlos, John. 1992. "Toward an Anthropometric History of African-Americans: The Case of the Free Blacks of Antebellum Maryland," in Claudia Goldin and Hugh Rockoff (eds.), Strategic Factors in Nineteenth Century American Economic History: A Volume to Honor Robert W. Fogel Chicago: University of Chicago Press for the National Bureau of Economic Research, Studies in Income and Wealth, Vol. 52, pp. 297-329.

Komlos, John. 1993a. “The secular trend in the biological standard of living in the United Kingdom, 1730-1860,” *Economic History Review* 46, 1:115-144.

Komlos, John. 1993b. "A Malthusian Episode Revisited: The Height of British and Irish Servants in Colonial America," *Economic History Review* 46, 4:768-82.

Komlos, John. 1996. "Anomalies in Economic History: Reflections on the 'Antebellum Puzzle'," *The Journal of Economic History* 56, 1:202-214.

Komlos, John. 1998. “Shrinking in a growing economy? The Mystery of Physical Stature during the Industrial Revolution,” *The Journal of Economic History* 58, 4:779–802.

Komlos, John. 1998. “On the Biological Standard of Living of African-Americans: the Case of the Civil War Soldiers,” in Komlos, John and Baten, Jörg (eds.), *The Biological Standard of Living in Comparative Perspectives: Proceedings of a Conference Held in Munich January 18-23, 1997*. Stuttgart: Franz Steiner Verlag, pp. 236-249.

Komlos, John. 2004. “How to (and How Not to) Analyze Deficient Height Samples: an Introduction,” *Historical Methods*, 37, 4:160-173.

Komlos, John and Peter Coclanis. 1997. “On the 'Puzzling' Antebellum Cycle of the Biological Standard of Living: the Case of Georgia,” *Explorations in Economic History* 34, 4:433-459.

Komlos, John, in collaboration with Michel Hau and Nicolas Bourguinat. 2003. “An Anthropometric History of Early-Modern France, 1666-1766,” *European Review of Economic History*, 7:159-189.

Komlos, John and Joo Han Kim. 1990. "Estimating Trends in Historical Heights," *Historical Methods* 23 (1990): 116-120.

Komlos, John and Helmut Küchenhoff, 2012. “The diminution of the physical stature of the English male population in the eighteenth century,” *Cliometrica* 6:45-62.

Kotz, S., Balakrishnan, N., and N. Johnson. 2000. *Continuous Multivariate Distributions.* New York: Wiley.

Kuhn, Thomas. 1962. *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press.

Kuznets, Simon. 1973. Modern Economic Growth: Findings and Reflections. *American Economic Review* 63, 3:247-258.

Lang, Stefan and Sunder, Marco. 2003. “Non-Parametric Regression with BayesX: A Flexible Estimation of Trends in Human Physical Stature in 19th Century America,” *Economics and Human Biology* 1, 1:77–89.

Lantzsch, Jana and Schuster, Klaus. 2009. “Socioeconomic status and physical stature in 19th-century Bavaria,” *Economics and Human Biology*, 7:46-54.

Lebergott, Stanley. 1964. *Manpower in Economic Growth: The American Record Since 1800.* New York: McGraw-Hill.

Margo, Robert A. 1996. “The Rental Price of Housing in New York City, 1830-1860,” *The Journal of Economic History* 56, 3:605-625.

Margo, Robert A. 2000. *Wages and Labor Markets in the United States, 1820-2860.* Chicago: University of Chicago Press.

Margo, Robert A. and Richard H. Steckel, 1982. “The Heights of American Slaves: New Evidence on Slave Nutrition and Health,” *Social Science History* 6, 4:516-538.

Margo, Robert A. and Richard H. Steckel, 1983. “Heights of Native-Born Whites during the Antebellum Period,” *The Journal of Economic History* 43, 1:167-174.

Margo, Robert A. and Georgia C. Villaflor, 1987. “The Growth of Wages in Antebellum America: New Evidence,” *The Journal of Economic History* 47, 4:873-895.

Mironov, Boris and A’Hearn, Brian. 2008. “Russian Living Standards under the Tsars: Anthropometric Evidence from the Volga,” *The Journal of Economic History* 68, 3:900-929.

Murdock, Eugene C. 1963. *Ohio’s Bounty System in the Civil War*. Columbus: Ohio State University Press, Ohio Historical Society.

Rees, Ray, Komlos, John, Ngo Van Long, and Ulrich Woitek. 2003. "Optimal Food Allocation in a Slave Economy," *Journal of Population Economics* 16:21-36.

Rothenberg, Winifred. 1979. “A Price Index for Rural Massachusetts, 1750-1855,” *The Journal of Economic History* 39, 4: 975-1001.

Rothenberg, Winifred. 1981. "The Market and Massachusetts Farmers, 1750-1855," *The Journal of Economic History* 41, 2:283-304.

Shannon, Fred A. 1928. *The Organization and Administration of the Union Army, 1861-1865*. Cleveland: Arthur H Clark Co.

Steckel, Richard H. 1983. "Height and Per Capita Income," *Historical Methods* 16, 1:1-7.

Steckel, Richard H. 1995. "The Health of American Slaves: New Evidence and Analysis," Paper delivered at the Annual Meeting of the Social Science History Association.

Steckel, Richard H. 1998. “Strategic Ideas in the Rise of the New Anthropometric History and Their Implications for Interdisciplinary Research,” *The Journal of Economic History* 58, 3:803-821.

Stiglitz, Joseph, Amartya Sen, and Jean-Paul Fitoussi. 2010. *Mismeauring Our Lives: Why GDP Doesn’t Add Up*. New York: The New Press.

Sunder, Marco. 2004. “The Height of Tennessee convicts: another Piece of the “antebellum puzzle,” *Economics and Human Biology* 2:74-86.

Sunder, Marco. 2011. “Upward and Onward: High-society American Women Eluded the Antebellum Puzzle,” *Economics and Human Biology* 9, 2:165-171.

Sunder, Marco. 2013. “The height gap in 19th-century America: Net-nutritional advantage of the elite increased at the onset of modern economic growth,” *Economics and Human Biology* 11, 3:245-258.

Weiss, Thomas, 1992. “U.S. Labor Force Estimates and Economic Growth, 1800-1860,” in Robert Gallman and John Wallis (eds.), *American Economic Growth and Standards of Living before the Civil War*, Chicago: University of Chicago Press, pp. 19-78.

Williamson, Jeffrey, and Peter Lindert. 1980. *American Inequality: A Macroeconomic History,* New York: Academic Press.

Yoo, Dongwoo. 2012. “Height and death in the Antebellum United States: A view through the lens of geographically weighted regression,” *Economics and Human Biology* 10:43-53.

Zehetmayer, Matthias. 2011. “The Postbellum Continuation of the Antebellum Puzzle: Stature in the US, 1847–1894.” *European Review of Economic History* 15, 2:313-327.

Zimran, Ariell. 2015. “Does Sample-Selection Bias Explain the Industrialization Puzzle? Evidence from Military Enlistment in the Nineteenth-Century United States,” Unpublished manuscrtipt, Department of Economics, Northwestern University.

Appendix Tables

Table A.1. Revised estimates of mean height (inches)

	Panel A Baseline			Panel B with age effects		
n	7,347					7,347
F(11, 7335)	6.05			F(18, 7,328)		6.36
prob > F	0.00					0.00
R^2	0.01					0.01
root mse	2.29					2.28
	coeff.	s.error	p-value	coeff.	s.error	p-value
birth cohort 1831		*reference*			*reference*	
birth cohort 1832	-0.26	0.24	0.28	-0.29	0.24	0.22
birth cohort 1833	-0.47	0.23	0.04	-0.53	0.26	0.04
birth cohort 1834	-0.33	0.22	0.13	-0.39	0.24	0.11
birth cohort 1835	-0.48	0.22	0.03	-0.74	0.25	0.00
birth cohort 1836	-0.45	0.22	0.04	-0.82	0.26	0.00
birth cohort 1837	-0.49	0.21	0.02	-0.98	0.27	0.00
birth cohort 1838	-0.64	0.21	0.00	-1.38	0.27	0.00
birth cohort 1839	-0.71	0.22	0.00	-1.48	0.28	0.00
birth cohort 1840	-0.75	0.23	0.00	-1.47	0.29	0.00
birth cohort 1841	-0.98	0.23	0.00	-1.87	0.30	0.00
birth cohort 1842	-1.39	0.27	0.00	-2.34	0.33	0.00
constant	69.11	0.20	0.00	70.05	0.28	0.00
age 23					*reference*	
age 24				-0.21	0.11	0.05
age 25				-0.48	0.12	0.00
age 26				-0.39	0.13	0.00
age 27				-0.76	0.14	0.00
age 28				-0.94	0.15	0.00
age 29				-0.85	0.17	0.00
age 30				-0.95	0.19	0.00

Test of age effects	
F(7, 7328)	6.74
Prob > F	0.00

Note: The table presents OLS estimates of a regression of height on dummy variables for birth-year. It replicates Bodenhorn, Guinnane and Mroz's specification with two differences in the estimating sample. While still comprising men aged 23-30 at enlistment, the sample is now restricted to native-born men with heights satisfying the minimum height requirement of 64 inches. Heteroskedasticity-robust standard errors are reported.
Panel B also includes age at enlistment. The test reported in the last rows of the table is an F-test of the joint significance of the age dummy variables.

Table A2. Revised estimates of mean height (inches)

	Panel A			Panel B		
n	7,347			7,347		
F(39, 7307)	3.47		F(15, 7331)	7.18		
prob > F	0.00			0.00		
R^2	0.02			0.01		
root mse	2.28			2.28		
	Panel A			Panel B		
	With age-specific trends			With enlistment year effects		
	coeff.	s.error	p-value	coeff.	s.error	p-value
birth cohort 1831	*reference*			*reference*		
birth cohort 1832	-0.26	0.25	0.29	-0.22	0.24	0.35
birth cohort 1833	-0.65	0.43	0.13	-0.42	0.23	0.07
birth cohort 1834	-0.69	0.87	0.42	-0.18	0.22	0.41
birth cohort 1835	-1.13	0.54	0.04	-0.33	0.22	0.14
birth cohort 1836	-1.10	0.81	0.18	-0.29	0.22	0.19
birth cohort 1837	-1.60	0.54	0.00	-0.34	0.22	0.12
birth cohort 1838	-1.66	0.71	0.02	-0.51	0.22	0.02
birth cohort 1839	-1.70	0.69	0.01	-0.49	0.23	0.03
birth cohort 1840	-1.74	0.74	0.02	-0.31	0.24	0.20
birth cohort 1841	-2.22	0.71	0.00	-0.52	0.25	0.04
birth cohort 1842	-2.60	0.72	0.00	-0.90	0.30	0.00
enlisted 1861		n.a.			*reference*	
enlisted 1862		n.a.		-0.05	0.07	0.45
enlisted 1863		n.a.		-0.35	0.13	0.01
enlisted 1864		n.a.		-0.45	0.09	0.00
enlisted 1865		n.a.		-0.49	0.12	0.00
age 23		*reference*				
age 24	0.09	0.27	0.74			
age 25	-0.54	0.39	0.16			
age 26	-0.20	0.29	0.51			
age 27	-0.76	0.50	0.13			
age 28	-1.01	0.52	0.05			
age 29	-0.95	0.63	0.13			
age 30	-1.21	0.67	0.07			
birth 1832 X age 29	-0.25	0.95	0.80			
birth 1833 X age 29	-0.09	0.85	0.91			
birth 1834 X age 28	0.21	0.75	0.78			
birth 1834 X age 30	0.16	0.86	0.85			
birth 1835 X age 26	-0.19	0.54	0.73			
birth 1835 X age 27	0.20	0.79	0.80			
birth 1835 X age 29	0.15	0.89	0.87			
birth 1835 X age 30	0.77	0.58	0.19			
birth 1836 X age 26	-0.19	0.52	0.72			
birth 1836 X age 28	0.03	0.69	0.97			
birth 1836 X age 29	0.54	0.56	0.34			
birth 1837 X age 24	0.00	0.53	1.00			
birth 1837 X age 25	0.54	0.60	0.37			

birth 1837 X age 27	0.39	0.68	0.57			
birth 1838 X age 24	-0.27	0.32	0.40			
birth 1838 X age 26	-0.08	0.36	0.83			
birth 1838 X age 27	-0.34	0.54	0.53			
birth 1839 X age 24	-0.56	0.40	0.17			
birth 1839 X age 25	-0.12	0.43	0.77			
birth 1840 X age 24	-0.32	0.39	0.41			
birth 1840 X age 25	0.14	0.52	0.79			
constant	70.32	0.70	0.00	69.11	0.20	0.00

Test of age-cohort interactions		Test of enlistment-year effects	
F(21, 7,307)	0.84	F(4, 7,331)	9.93
Prob > F	0.67	Prob > F	0.00

Note: The table presents OLS estimates of a regression of height on dummy variables for birth-year and age at enlistment, along with interactions between the two. It replicates Bodenhorn, Guinnane and Mroz's specification with two differences in the estimating sample. While still comprising men aged 23-30 at enlistment, the sample is now restricted to native-born men with heights satisfying the minimum height requirement of 64 inches. Heteroskedasticity-robust standard errors are reported. The test result reported in the last rows of the table is an F-test of the joint significance of the age – birth-year interactions (Panel A) and of the joint significance of the enlistment-year dummy variables (Panel B).

Table A3. Revised estimates of mean height (inches) by enlistment-year and birth-year effects with enlistment-year – specific trends.

n	7,347			
F(39, 7307)	3.47			
prob > F	0.00			
R^2	0.02			
root mse	2.29			
	coeff.	s.error	t-stat.	p-value
birth cohort 1831	*reference*			
birth cohort 1832	-0.24	0.29	-0.83	0.404
birth cohort 1833	-0.44	0.26	-1.73	0.084
birth cohort 1834	-0.24	0.25	-0.94	0.348
birth cohort 1835	-0.30	0.25	-1.21	0.227
birth cohort 1836	-0.42	0.25	-1.72	0.086
birth cohort 1837	-0.29	0.24	-1.24	0.216
birth cohort 1838	-0.44	0.24	-1.88	0.061
birth cohort 1839	-0.76	0.52	-1.46	0.145
birth cohort 1840	-0.34	0.50	-0.68	0.498
birth cohort 1841	-0.99	0.64	-1.56	0.119
birth cohort 1842	-1.47	0.62	-2.38	0.017
enlisted 1861	*reference*			
enlisted 1862	-0.02	0.26	-0.08	0.933
enlisted 1863	-0.19	0.39	-0.48	0.630
enlisted 1864	-0.29	0.24	-1.24	0.214
enlisted 1865	0.08	0.55	0.15	0.884
birth 1833 X enlistment 1862	-0.01	0.33	-0.02	0.982
birth 1833 X enlistment 1863	-0.02	0.57	-0.03	0.975
birth 1834 X enlistment 1862	-0.02	0.33	-0.05	0.963
birth 1835 X enlistment 1862	-0.15	0.32	-0.47	0.636
birth 1835 X enlistment 1863	-0.44	0.51	-0.86	0.39
birth 1835 X enlistment 1864	-0.12	0.33	-0.36	0.721
birth 1835 X enlistment 1865	-0.14	0.64	-0.23	0.821
birth 1836 X enlistment 1862	0.18	0.32	0.56	0.578
birth 1836 X enlistment 1863	-0.03	0.50	-0.06	0.956
birth 1836 X enlistment 1864	-0.14	0.32	-0.44	0.66
birth 1836 X enlistment 1865	0.05	0.64	0.08	0.938
birth 1837 X enlistment 1862	-0.08	0.31	-0.24	0.809
birth 1837 X enlistment 1863	-0.10	0.52	-0.19	0.848
birth 1837 X enlistment 1864	-0.16	0.31	-0.53	0.595
birth 1837 X enlistment 1865	-1.18	0.64	-1.86	0.063
birth 1838 X enlistment 1862	-0.16	0.30	-0.51	0.61
birth 1838 X enlistment 1863	-0.35	0.55	-0.64	0.521
birth 1838 X enlistment 1864	0.02	0.31	0.06	0.949
birth 1838 X enlistment 1865	-1.18	0.62	-1.91	0.056
birth 1839 X enlistment 1862	0.30	0.56	0.54	0.591
birth 1839 X enlistment 1864	-0.09	0.51	-0.18	0.854

birth 1840 X enlistment 1864	-0.13	0.49	-0.26	0.793
birth 1840 X enlistment 1865	-0.67	0.52	-1.29	0.196
birth 1841 X enlistment 1864	0.28	0.62	0.45	0.650
constant	69.11	0.20	342.76	0.000
test of enlistment-year-birth-cohort interaction				
F(24, 7307)	1.07			
Prob > F	0.37			

Note: The table presents OLS estimates of a regression of height on dummy variables for birth-year and age at enlistment, along with interactions between the two. It replicates Bodenhorn, Guinnane and Mroz's specification with two differences in the estimating sample. While still comprising men aged 23-30 at enlistment, the sample is now restricted to native-born men with heights satisfying the minimum height requirement of 64 inches. Heteroskedasticity-robust standard errors are reported. The test result reported in the last rows of the table is an F-test of the joint significance of the enlistment-year – birth-year interactions.

Table A4. New estimates of mean height (inches) by enlistment- and birth-year

n	23,662			
F(43, 23618)	43.99			
Prob > F	0.00			
R^2	0.07			
root mse	2.26			
	coeff.	s.error	t-stat.	p-value
age18	-0.78	0.10	-7.74	0.00
age19	-0.32	0.09	-3.51	0.00
age20	-0.11	0.08	-1.32	0.19
age21	-0.05	0.07	-0.71	0.48
age 22+	*reference*			
birth cohort 1820	0.11	0.15	0.74	0.46
birth cohort 1821	0.50	0.15	3.29	0.00
birth cohort 1822	0.23	0.16	1.45	0.15
birth cohort 1823	0.41	0.17	2.49	0.01
birth cohort 1824	0.45	0.16	2.88	0.00
birth cohort 1825	-0.04	0.15	-0.26	0.80
birth cohort 1826	0.39	0.14	2.79	0.01
birth cohort 1827	0.21	0.12	1.69	0.09
birth cohort 1828	0.41	0.13	3.26	0.00
birth cohort 1829	0.38	0.12	3.07	0.00
birth cohort 1830	0.36	0.12	3.07	0.00
birth cohort 1831	0.46	0.12	3.91	0.00
birth cohort 1832	0.35	0.11	3.19	0.00
birth cohort 1833	0.19	0.11	1.77	0.08
birth cohort 1834	0.25	0.10	2.51	0.01
birth cohort 1835	0.27	0.10	2.75	0.01
birth cohort 1836	0.30	0.09	3.18	0.00
birth cohort 1837	0.07	0.09	0.78	0.44
birth cohort 1838	0.06	0.09	0.7	0.48
birth cohort 1839	-0.04	0.09	-0.43	0.67
birth cohort 1840	*reference*			
birth cohort 1841	-0.12	0.08	-1.51	0.13
birth cohort 1842	-0.12	0.09	-1.4	0.16
birth cohort 1843	-0.24	0.09	-2.54	0.01
birth cohort 1844	-0.39	0.11	-3.63	0.00
birth cohort 1845	-0.36	0.12	-2.91	0.00
birth cohort 1846	-0.60	0.13	-4.54	0.00
birth cohort 1847	-0.53	0.18	-3.03	0.00
enlistment 1861	*reference*			
enlistment 1862	-0.09	0.04	-2.22	0.03
enlistment 1863	-0.32	0.07	-4.47	0.00
enlistment 1864	-0.24	0.05	-4.92	0.00
enlistment 1865	-0.49	0.07	-7.3	0.00
birth mid-Atlantic	*reference*			

birth north-central	0.48	0.03	13.98	0.00
birth New England	0.06	0.05	1.07	0.29
birth other	-1.17	0.34	-3.45	0.00
birth south-Atlantic	0.40	0.07	5.62	0.00
birth south-central	0.58	0.07	8.36	0.00
farmer	*reference*			
professional	-0.46	0.06	-8.02	0.00
artisan	-0.36	0.04	-8.77	0.00
low-skilled	-0.51	0.04	-11.91	0.00
constant	68.48	0.07	959.51	0.00
Test of enlistment year effects				
F(4, 23618)	16.19			0.00

Note: The table presents OLS estimates of a regression of height on dummies for age at measurement, birth-year, birth-region, enlistment-year, and occupational group. Heteroskedasticity-robust standard errors are reported. The estimating sample is native-born men aged 18-50 at measurement, with heights satisfying the minimum height requirement of 64 inches. The test result reported in the last rows of the table is an F-test of the joint significance of the enlistment-year dummies.

Table A5. New estimates of covariates of height (inches) by birth-year and recruiting-regime

		Panel A				Panel B	
n	23,662					23,662	
F(40, 23621)	51.17			F(67, 23594)		31.76	
Prob > F	0.00					0.00	
R^2	0.073					0.075	
root mse	2.26					2.26	
	coeff.	s.error	p-value		coeff.	s.error	p-value
age 18	-0.70	0.10	0.00		-0.44	0.13	0.00
age 19	-0.28	0.09	0.00		-0.11	0.12	0.36
age 20	-0.06	0.08	0.44		-0.02	0.10	0.83
age 21	-0.02	0.07	0.75		-0.03	0.08	0.73
age 22+	*reference*				*reference*		
birth year 1820	0.13	0.14	0.35		0.32	0.19	0.09
birth year 1821	0.49	0.15	0.00		0.66	0.22	0.00
birth year 1822	0.23	0.17	0.17		0.18	0.24	0.45
birth year 1823	0.41	0.18	0.02		0.35	0.23	0.12
birth year 1824	0.45	0.16	0.01		0.29	0.21	0.17
birth year 1825	-0.04	0.14	0.76		0.12	0.19	0.53
birth year 1826	0.40	0.15	0.01		0.34	0.21	0.10
birth year 1827	0.20	0.13	0.13		0.10	0.16	0.54
birth year 1828	0.41	0.12	0.00		0.63	0.15	0.00
birth year 1829	0.38	0.13	0.00		0.54	0.16	0.00
birth year 1830	0.36	0.12	0.00		0.38	0.15	0.01
birth year 1831	0.46	0.12	0.00		0.58	0.14	0.00
birth year 1832	0.34	0.11	0.00		0.46	0.13	0.00
birth year 1833	0.19	0.10	0.07		0.31	0.13	0.01
birth year 1834	0.26	0.10	0.01		0.37	0.12	0.00
birth year 1835	0.27	0.10	0.01		0.29	0.12	0.02
birth year 1836	0.30	0.10	0.00		0.34	0.11	0.00
birth year 1837	0.08	0.09	0.39		0.13	0.11	0.23
birth year 1838	0.07	0.09	0.45		0.09	0.11	0.38
birth year 1839	-0.03	0.09	0.74		0.00	0.10	0.99
birth year 1840	*reference*				*reference*		
birth year 1841	-0.15	0.08	0.08		-0.14	0.10	0.17
birth year 1842	-0.15	0.09	0.10		-0.21	0.12	0.08
birth year 1843	-0.28	0.09	0.00		-0.51	0.13	0.00
birth year 1844	-0.47	0.10	0.00		-0.75	0.14	0.00
birth year 1845	-0.41	0.12	0.00		-0.95	0.23	0.00
birth year 1846	-0.67	0.13	0.00		-1.36	0.36	0.00
birth year 1847	-0.79	0.15	0.00		-1.65	0.36	0.00
early war	*reference*				*reference*		
late war	-0.25	0.04	0.00		-0.15	0.13	0.26
birth mid-Atlantic	*reference*				*reference*		
birth north-central	0.48	0.03	0.00		0.48	0.03	0.00
birth New England	0.06	0.05	0.27		0.05	0.05	0.34
birth other	-1.14	0.31	0.00		-1.15	0.31	0.00

birth south-Atlantic	0.39	0.07	0.00	0.39	0.07	0.00
birth south-central	0.59	0.07	0.00	0.58	0.07	0.00
farmer	*reference*			*reference*		
professional	-0.46	0.06	0.00	-0.46	0.06	0.00
artisan	-0.36	0.04	0.00	-0.37	0.04	0.00
low-skilled	-0.50	0.04	0.00	-0.51	0.04	0.00
constant	68.42	0.07	0.00	68.40	0.08	0.00
late war X b. 1820				-0.41	0.29	0.16
late war X b. 1821				-0.41	0.31	0.19
late war X b. 1822				0.06	0.34	0.85
late war X b. 1823				0.13	0.37	0.72
late war X b. 1824				0.32	0.32	0.31
late war X b. 1825				-0.45	0.29	0.12
late war X b. 1826				0.09	0.30	0.77
late war X b. 1827				0.20	0.27	0.47
late war X b. 1828				-0.58	0.25	0.02
late war X b. 1829				-0.45	0.29	0.12
late war X b. 1830				-0.10	0.26	0.70
late war X b. 1831				-0.35	0.25	0.16
late war X b. 1832				-0.36	0.23	0.12
late war X b. 1833				-0.40	0.22	0.08
late war X b. 1834				-0.38	0.22	0.09
late war X b. 1835				-0.07	0.22	0.75
late war X b. 1836				-0.16	0.21	0.44
late war X b. 1837				-0.22	0.20	0.27
late war X b. 1838				-0.12	0.21	0.57
late war X b. 1839				-0.12	0.19	0.51
late war X b. 1841				-0.09	0.19	0.65
late war X b. 1842				-0.03	0.19	0.87
late war X b. 1843				0.32	0.19	0.10
late war X b. 1844				0.27	0.19	0.14
late war X b. 1845				0.34	0.25	0.18
late war X b. 1846				0.40	0.36	0.27
late war X b. 1847				0.54	0.37	0.15

test of recruitment-period -- interaction effects

F(27, 23594) 1.88 0.00

Note: The table presents OLS estimates of a regression of height on dummy variables for age at measurement, birth-year, birth-region, occupational group, and recruiting regime. The two recruiting regimes are "early-war" (April 1861-February 1863) and "late-war" (March 1863 – May 1865). Heteroskedasticity-robust standard errors are reported. The estimating sample is native-born men aged 18-50 at enlistment with heights satisfying the minimum height requirement of 64 inches. Panel B in addition presents interactions between birth-year and recruiting regime. The test reported in the last lines is an F-test of the joint significance of the interaction effects.

Table A6. New estimates of mean height (inches) for the 90-day enlistment windows

N		3,736			7,133			2,703	
F(38, 3697)		7.32		F(39,7093)	12.50		F(39, 2663)	28.21	
Prob > F		0.00			0.00			0.00	
R^2		0.07			0.06			0.07	
root mse		2.33			2.27			2.17	
	14 August - 11 November 1861			11 July - 9 October 1862			6 August - 4 November 1864		
	Panel A			Panel B			Panel C		
	coeff.	s.error	p-value	coeff.	s.error	p-value	coeff.	s.error	p-value
age 18	-0.10	0.31	0.74	-0.72	0.41	0.08	-1.41	0.40	0.00
age 19	-0.17	0.31	0.57	-0.55	0.34	0.10	0.31	0.66	0.64
age 20	0.51	0.28	0.07	-0.03	0.32	0.93	-0.07	0.91	0.93
age 21	0.37	0.26	0.17	-0.09	0.30	0.76	0.43	0.67	0.53
age 22+	*reference*			*reference*			*reference*		
Year of Birth									
BY 1820	1.02	0.45	0.02	0.33	0.23	0.15	-0.04	0.35	0.91
BY 1821	0.81	0.39	0.04	0.42	0.33	0.20	0.45	0.37	0.22
BY 1822	0.88	0.64	0.17	-0.02	0.31	0.94	0.42	0.36	0.24
BY 1823	0.75	0.54	0.16	0.54	0.32	0.10	0.02	0.46	0.97
BY 1824	0.93	0.49	0.06	0.23	0.30	0.45	0.28	0.32	0.38
BY 1825	0.34	0.48	0.48	0.22	0.24	0.35	-0.02	0.37	0.96
BY 1826	0.76	0.47	0.11	0.36	0.29	0.21	0.83	0.39	0.03
BY 1827	0.55	0.37	0.13	0.15	0.22	0.50	0.30	0.32	0.34
BY 1828	1.48	0.39	0.00	0.54	0.21	0.01	-0.01	0.30	0.98
BY 1829	1.05	0.36	0.00	0.43	0.22	0.06	0.03	0.35	0.92
BY 1830	1.02	0.36	0.00	0.60	0.21	0.01	0.43	0.40	0.28
BY 1831	1.47	0.35	0.00	0.30	0.20	0.13	0.51	0.32	0.11
BY 1832	0.62	0.34	0.07	0.53	0.18	0.00	0.30	0.31	0.34
BY 1833	0.90	0.32	0.01	0.18	0.17	0.28	-0.28	0.31	0.37
BY 1834	0.60	0.32	0.06	0.44	0.17	0.01	0.21	0.32	0.53
BY 1835	0.69	0.31	0.03	0.30	0.17	0.08	0.36	0.33	0.28
BY 1836	0.50	0.31	0.11	0.48	0.16	0.00	-0.05	0.31	0.88
BY 1837	0.37	0.29	0.21	0.17	0.16	0.29	0.16	0.29	0.59
BY 1838	0.59	0.31	0.06	0.12	0.15	0.41	0.19	0.32	0.54
BY 1839	0.35	0.29	0.23	-0.01	0.14	0.96	0.09	0.29	0.77
BY 1840	*reference*			*reference*			*reference*		
BY 1841	-0.18	0.32	0.58	-0.04	0.31	0.91	-0.17	0.29	0.55
BY 1842	0.19	0.34	0.58	-0.20	0.33	0.55	-0.16	0.28	0.57
BY 1843	-0.67	0.28	0.02	-0.01	0.34	0.97	-0.73	0.69	0.29
BY 1844	-0.78	0.40	0.05	-0.29	0.42	0.48	-0.32	0.92	0.73
BY 1845	-0.85	0.47	0.07	-1.09	0.46	0.02	-1.03	0.68	0.13
BY 1846	-1.17	0.98	0.24	-0.30	0.61	0.62	0.23	0.44	0.60
BY 1847	n.a.			-0.76	0.43	0.08	-0.79	0.29	0.01
Birthplace									
mid-Atlantic	*reference*			*reference*			*reference*		

north-central	0.28	0.09	0.00	0.62	0.06	0.00	0.48	0.10	0.00
New England	-0.15	0.13	0.25	0.09	0.09	0.30	0.18	0.19	0.35
other	-1.62	1.52	0.29	-3.32	0.10	0.00	-1.44	0.73	0.05
south-Atlantic	0.22	0.18	0.22	0.47	0.13	0.00	0.35	0.21	0.11
south-central	0.39	0.15	0.01	0.72	0.17	0.00	0.38	0.17	0.02
farmer	*reference*			*reference*			*reference*		
professional	-0.50	0.15	0.00	-0.42	0.11	0.00	-0.69	0.19	0.00
artisan	-0.30	0.11	0.01	-0.46	0.07	0.00	-0.08	0.13	0.54
low-skilled	-0.50	0.11	0.00	-0.49	0.09	0.00	-0.32	0.11	0.00
constant	68.23	0.26	0.00	68.32	0.10	0.00	68.16	0.21	0.00

Note: The table presents OLS estimates of a regression of height on dummy variables for age at measurement, birth-year, birth-region, and occupational group. Heteroskedasticity-robust standard errors are reported. The estimating sample is native-born men aged 18-50 at enlistment with heights satisfying the minimum height requirement of 64 inches.
Panel A: restricted to those who enlisted between 14 August and 11 November 1861.
Panel B: restricted to those who enlisted between 11 July and 9 October 1862.
Panel C: restricted to those who enlisted between 6 August and 4 November 1864.

Table A7. New estimates of mean height (inches) among draftees, substitutes, and Rejects

n	1,869					1,234	
F(39, 1830)	4.36			F(48, 1185)		1.62	
Prob > F	0.00					0.01	
R^2	0.07					0.06	
root mse	2.29					3.01	
	Panel A					Panel B	
	Draftees and Substitutes					Rejects	
	coeff.	s.error	p- value		coeff.	s.error	p-value
age 18	-0.16	0.54	0.76		-0.28	1.55	0.86
age 19	0.12	0.49	0.80		0.54	1.39	0.70
age 20	0.13	0.42	0.75		0.31	1.07	0.77
age 21	0.00	0.31	0.99		0.70	0.72	0.33
age 22+		*reference*				*reference*	
birth year 1820	0.14	0.54	0.80		0.40	0.69	0.56
birth year 1821	0.64	0.50	0.20		0.04	0.64	0.95
birth year 1822	0.63	0.58	0.28		-0.14	0.67	0.83
birth year 1823	0.18	0.49	0.72		1.26	0.65	0.06
birth year 1824	1.50	0.45	0.00		0.38	0.68	0.58
birth year 1825	0.79	0.42	0.06		0.03	0.65	0.97
birth year 1826	-0.23	0.47	0.63		0.53	0.65	0.42
birth year 1827	1.06	0.53	0.05		-0.35	0.67	0.60
birth year 1828	0.17	0.35	0.62		-0.01	0.66	0.99
birth year 1829	0.16	0.39	0.68		0.38	0.65	0.56
birth year 1830	0.61	0.40	0.13		0.32	0.68	0.64
birth year 1831	0.51	0.41	0.21		-0.08	0.70	0.90
birth year 1832	0.27	0.36	0.46		0.08	0.71	0.91
birth year 1833	0.23	0.35	0.50		-0.25	0.71	0.73
birth year 1834	0.66	0.38	0.08		-0.52	0.72	0.47
birth year 1835	0.01	0.36	0.98		0.75	0.71	0.29
birth year 1836	0.33	0.37	0.37		0.24	0.70	0.73
birth year 1837	0.58	0.36	0.11		-0.32	0.67	0.64
birth year 1838	-0.16	0.38	0.68		0.02	0.68	0.97
birth year 1839	0.77	0.34	0.02		0.55	0.67	0.41
birth year 1840		*reference*				*Reference*	
birth year 1841	0.37	0.34	0.27		0.00	0.72	1.00
birth year 1842	0.04	0.33	0.90		-0.47	0.75	0.53
birth year 1843	-0.04	0.38	0.91		-0.04	0.84	0.96
birth year 1844	-0.05	0.48	0.92		-0.85	1.10	0.44
birth year 1845	-0.02	0.54	0.97		-1.15	1.37	0.40
birth year 1846	-0.50	0.58	0.38		-1.78	1.60	0.27
birth year 1847	-0.67	0.64	0.30		-2.10	1.76	0.23
birth mid-Atlantic		*reference*				*reference*	
birth north-central	0.60	0.12	0.00		0.29	0.26	0.25
birth New England	0.30	0.19	0.12		0.43	0.36	0.24
birth other		(omitted)			0.32	0.25	0.20

birth south-Atlantic	0.27	0.23	0.24	0.31	0.33	0.34
birth south-central	0.51	0.21	0.02	0.49	0.40	0.22
farmer	*reference*			*reference*		
professional	-0.55	0.26	0.04	-0.59	0.29	0.04
artisan	-0.33	0.16	0.04	-0.83	0.24	0.00
low-skilled	-0.30	0.15	0.05	-0.68	0.26	0.01
substitute	-0.18	0.14	0.20	n.a.		
no enlistment year					*reference*	
enlistment 1864				-0.10	0.23	0.66
enlistment 1865				0.18	0.24	0.45
constant	67.72	0.26	0.00	68.13	0.55	0.00

Note: The table presents OLS estimates of regressions of height on dummy variables for age at measurement, birth-year, birth-region, and occupational group. Heteroskedasticity-robust standard errors are reported. The estimating sample is native-born men aged 18-50 at enlistment with heights satisfying the minimum height requirement of 64 inches.
Panel A: draftees and substitutes. Because almost the entire sample enlisted under the late-war recruiting regime, there is no control for enlistment period.
Panel B: recruits rejected by the army. For a significant fraction of the sample, enlistment year was missing and assumed to be 1863; this is the reference group.

Table A8. New estimates of population mean height (inches) by birth-year

n	14,913			
Wald chi2(43)	1023.35			
Prob > chi2	0.00			
	coeff.	s.error	t-stat.	p-value
age 18	-0.56	0.19	-2.93	0.00
age 19	-0.12	0.16	-0.74	0.46
age 20	-0.03	0.14	-0.19	0.85
age 21	-0.03	0.12	-0.26	0.79
age 22+	*reference*			
birth year 1820	0.38	0.21	1.78	0.08
birth year 1821	0.80	0.24	3.25	0.00
birth year 1822	0.25	0.28	0.89	0.38
birth year 1823	0.45	0.26	1.71	0.09
birth year 1824	0.37	0.25	1.50	0.13
birth year 1825	0.15	0.22	0.65	0.51
birth year 1826	0.42	0.24	1.76	0.08
birth year 1827	0.12	0.19	0.65	0.51
birth year 1828	0.74	0.18	4.21	0.00
birth year 1829	0.64	0.18	3.48	0.00
birth year 1830	0.46	0.18	2.58	0.01
birth year 1831	0.68	0.16	4.10	0.00
birth year 1832	0.55	0.15	3.60	0.00
birth year 1833	0.37	0.15	2.49	0.01
birth year 1834	0.44	0.14	3.13	0.00
birth year 1835	0.35	0.14	2.49	0.01
birth year 1836	0.41	0.13	3.02	0.00
birth year 1837	0.16	0.13	1.18	0.24
birth year 1838	0.11	0.13	0.86	0.39
birth year 1839	-0.01	0.12	-0.04	0.97
birth year 1840	*reference*			
birth year 1841	-0.17	0.12	-1.43	0.15
birth year 1842	-0.26	0.15	-1.72	0.09
birth year 1843	-0.65	0.17	-3.79	0.00
birth year 1844	-0.98	0.20	-4.93	0.00
birth year 1845	-1.23	0.32	-3.80	0.00
birth year 1846	-1.89	0.58	-3.28	0.00
birth year 1847	-2.55	0.63	-4.07	0.00
birth mid-Atlantic	*reference*			
birth north-central	0.63	0.05	11.89	0.00
birth New England	0.05	0.08	0.60	0.55
birth other	-3.69	2.58	-1.43	0.15
birth south-Atlantic	0.55	0.11	5.17	0.00
birth south-central	0.76	0.11	7.04	0.00
farmer	*reference*			
professional	-0.54	0.09	-5.98	0.00

artisan	-0.49	0.06	-7.94	0.00
low-skilled	-0.66	0.07	-9.46	0.00
volunteer	*reference*			
substitute	-0.50	0.34	-1.47	0.14
drafted	-0.50	0.27	-1.85	0.07
illiterate	-0.32	0.11	-3.01	0.00
disciplined	-0.11	0.06	-1.99	0.05
constant	68.21	0.10	699.23	0.00
standard deviation	2.51	0.02	111.42	0.00

Note: The table presents truncated maximum likelihood estimates of a regression of height on dummy variables for age at measurement, birth-year, birth-region, occupational group, enlistment status, literacy, and disciplinary record. The estimating sample is native-born men aged 18-50 at enlistment with heights of at least 64 inches, who enlisted before 1 March, 1863. The estimate in the last row of the table refers to the standard deviation of the normally-distributed regression disturbance.

Appendix B. Estimation of military compensation relative to civilian earnings

We estimate the compensation per recruit per annum for the early war years until February, 1963 and for the late war period thereafter. We use total bounty payments as reported in Table VIII of the "Supplementary Tables" to Lewis and Goldin's (1975) publication. The term of service is given in our data set for each enlistee. It was 3 years for almost everyone in the early period and on average 1.8 years during the later period. We divide total bounty payments by total recruits and by average term to obtain annual equivalent bounty payments per man in current dollars. These were converted to constant 1860 dollars using prince index values of 115 (early) and 170 (late) which are the averages for the respective periods. The estimate indicates that total military compensation increased relative to urban and farm earnings by $135 and $123 respectively during the course of the war (in 1860 dollars). This was an increase of between 39 and 66 percentage points in the military/civilian compensation ratio. This is the case although we have left veteran's benefits out of consideration. To the extent that the anticipation of such benefits increased during the war with the North's successes on the battlefield, it would tend to support the notion that the pecuniary benefits of being in the military increased over time.[42]

	Military (M)			Civilian (C)		M - C		M / C	
	Bounty	*Pay*	Total	Urban	Rural	Urban	Rural	Urban	Rural
Early war	*51*	*174*	224	349	208	-125	16	0.64	1.08
Late war	*193*	*133*	326	316	187	10	139	1.03	1.74
change	*142*	*-41*	102	-33	-21	135	123	0.39	0.66

Note: All figures in 1860 dollars. Military pay includes Lewis and Goldin's 33% increment for rations, but not their $3.50 per month clothing allowance. (We assumed the latter to be in current dollars, converting it first an 1860 basis, then subtracting it from Lewis and Goldin's total.) We do not think that the clothing allowance entered into the soldier's decision to enter the military.
Sources: Soldiers pay: Table XII, "Supplementary Tables," Lewis and Goldin (1975). Price index: David and Solar (1977) as reproduced in Carter et al. 2006, Table Cc1-2. Urban wages: Lebergott (1964) as reproduced in Carter et al. 2006, Table Ba4280-4282. Farm wages: Lebergott (1964) pp. 510, 523, 528, and 539 as reproduced in Lewis and Goldin, *loc. cit.* Recruits: Gould (1869), vol. I, p. 80.

	Federal bounties		State bounties	
	Early war	Late war	Early war	Late war
Total	68,721	231,503	117,000	338,000
Per recruit	65	240	110	351
Per recruit year	22	134	37	195

Note; These are in current dollars.
Source: Table VIII of the "Supplementary Tables" to Lewis and Clark (1975)

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42 Yet another consideration is that the size of the army was increasing over time and the number of eligible men who have not yet been engaged declined so that the demand for military personnel was moving up the supply curve of potential enlistees. This implies that the pay must have been increasing. We owe this suggestion to Frank Lewis.

Period	Recruits (000)	Period	Recruits (000)
April 1861	750	July 1862	467
July 1863	439	July 1864	370
Total	2,026		

Source: Gould, 1869, Vol. 1, p. 80.