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NUTRITIONAL STATUS AND AGRICULTURAL SURPLUSES IN THE ANTEBELLUM UNITED STATES

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ABSTRACT

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Abstract

We model the relationship between local agricultural surpluses, nutritional status, and height, and we test the hypothesis that adult height is positively correlated with the local production of nutrition in infancy. We test the hypothesis on two samples of Union Army recruits - one consisting of white recruits and the other black recruits. The white sample shows that a local protein surplus one standard deviation above the mean yielded an additional 0.10 inches in adult height, and a similar deviation in surplus calorie production yielded an additional 0.20 inches. For blacks, however, the effect was probably negligible.

Key Words: Nutrition, stature, agricultural surplus

1. Issues

The connection between net nutritional status during key periods of *homo sapiens'* biological development and adult height has been well established in the literature on human growth.[1] In particular the consumption of nutrients during infancy plays an important role in stature.[2] Over the past two decades, economic historians have explored the connection between the average stature of various (primarily Western) populations and standard measures of economic growth (such as income per capita) and the distribution of income. The findings of these studies have led to a number of disputes concerning the characterization of Western economic growth and development over the past three hundred years or so.

The long-run trend in the average heights of western populations, like the trend in measures of output, has been positive - that is, populations have on average become taller and

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[1]For an excellent recent survey of this literature, see Steckel (1995).

[2]*Homo sapiens* experience two periods of accelerated velocity in height during biological development. The first occurs during infancy, and the velocity of this growth spurt is roughly twice that achieved during the second, or adolescent, spurt (Tanner, 1978).

richer over time - but there have been fluctuations. There have been some subperiods of that history during which the population got shorter, and this may have occurred even while output per person was rising. One explanation of such a paradox holds that the distribution of output became more unequal, so that although output or income per capita continued to rise, average height fell as a substantial proportion of the population at the lowest income levels experienced a decline in net nutrition. Of course, inferring such an outcome from the available data is not always a straightforward exercise, and thus the seeming paradox remains unresolved.

The chief difficulty in unraveling this paradoxical issue is that the available evidence has been predominantly aggregate data, while the underlying biological relationship between an individual's stature and nutritional status is clearly a microeconomic issue.[3] In his recent survey of the literature on the relationship between stature and the standard of living, Richard Steckel argued for a more micro-level approach. In his words, "It would be possible to test the argument that declines in inputs to net nutrition were responsible [for the antebellum decline in heights] by examining information on diets, ... and systems of food distribution (1995, p. 1928-30)." In other words an individual's adult height should be correlated with information related to one's diet and disease history, which in turn are likely to be related to the distribution of food and the incidence of disease in the location in which one spent infancy and adolescence.[4]

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[3] The problems of using aggregate data include the actual measurement of average height and explaining the movement in average height over time. Steckel (1995) contains a broad summary of the issues. On the problems of measurement see the debate between Komlos (1993) and Floud, Wachter, and Gregory (1993), and on the point of explaining changes in average height over time see the debate between Gallman (1996) and Komlos (1996).

[4] Obviously, one would like to have an individual's diet during infancy and adolescence as well as his disease history to test the nutrition-stature hypothesis directly. Contemporary longitudinal studies may provide something close to that ideal, but for historical data on height, local conditions must serve as a substitute for individual experience.

In this paper we address this issue by testing the hypothesis that local economic conditions, especially the production of nutrients, namely protein and calories, affected adult height. To conduct this test we link two samples of Union Army recruits from the Civil War, which contain data on the adult height of the recruits, with economic conditions in the counties in which they were born. The importance of this analysis is twofold. First, it offers a direct historical test of the hypothesis that local economic conditions affect individual nutritional status, in particular the propinquity to food.[5] Second, it contributes to the standard of living debate by identifying cross-sectionally the magnitude of the relationship between the economic conditions and nutritional status.

2. Model

As noted above, the literature on human growth suggests that the stature of the *ith* individual is a function of genetic factors and environmental conditions during periods of growth. Among the growth periods, infancy is critical because the velocity during that period is on average twice what it is during any other period of growth. The relationship between genetic and environmental factors is itself both complex and not entirely predictable for any specific individual, but as Steckel notes, "... stature is ultimately a function of access to resources (1995, p. 1908)."

The link between access to resources (nutrition) in infancy and adult height, can be expressed more formally as follows:

$$H=f(R,G) \qquad (1)$$

[5]This hypothesis was first raised by Komlos (1985 and 1987).

where H is adult height; R measures access to resources in infancy, and G represents genetic factors.[6] R itself can be thought of as a measure of access to net nutrients, N, after the claims of disease, D, and physical exertion, E, have been met.

$$R=N-D-E \qquad (2)$$

Equations (1) and (2) represent biological relationships, and might seem as though they would relate to each other in some fixed way. There is certainly some mechanical relationship, but to a certain extent, the levels of the variables in (2) are determined by choices. Nutrients, healthier surroundings, and an attenuation of exertion can all be purchased, so that at the margin, changes in relative prices would be expected to influence the purchases of these "goods".[7] Parents who value the nutritional status of their children would be expected to purchase nutrients, and if parents were sufficiently informed and economically rational, then their purchases would be negatively related to the relative price of nutrients, P_N, and positively related to wealth, W.[8]

$$N=g(P_N,W) \qquad (3)$$

If nutrients were produced and distributed in competitive markets, then arbitrage would dissipate price differentials across locations, at least among tradeables, except those resulting from transaction costs. For example, protein is a valuable nutrient for growth; wheaten loaf, pork, and fresh milk are good, though not equally good, sources of protein; a family living on a

[6] We exclude the effect of genetics in our analysis because although, "Genes are important determinants of individual height,..genetic differences approximately cancel in comparisons of averages across most populations.." (Steckel, 1995, 1903) and because we do not have evidence on the heights of the parents of the recruits in our sample.

[7] We assume that parents consider their childrens' nutritional status to be a normal good. For a model and discussion of these relationships see Behrman and Deolalikar (1988).

[8] Here we mean wealth broadly defined, including human capital as well as financial capital or physical wealth; thus income would be the flow from the family's stock of labor and capital.

farm in central Illinois would face a lower price of protein than one living in Chicago, because the costs of storing, processing, and shipping wheat, pork, and milk from surrounding areas to Chicago, while arguably low, are not zero.[9] Thus two families, alike in all respects except location would face different relative prices and thus be expected to consume different bundles of goods.[10] In this case the farm family and its neighbors would face a lower relative price of protein for wheat and pork than the urban family, and the farm family would be expected to thus consume more protein from wheat and pork than the urban family, *ceteris paribus*.[11] Following this argument, and by substitution, the adult height of the *ith* individual would be positively related to the supply of nutrients in the locale in which he spent his infancy, N_i^s, *ceteris paribus* of course.

$$\delta H_i / \delta N_i^s > 0 \qquad (4)$$

Thus, below, we test the hypothesis that there is a net positive relationship between access to nutrition in infancy and adult height.[12] In other words, propinquity to food might be more

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[9]The gains from division of labor and scale economies in production in response to urban demand might have provided an incentive for food processors to locate in or near urban areas, which would have offset the farmgate-retail price differential to some extent.

[10]The difference in bundles could take a different form. If the cost of shipping protein via one commodity, say wheat, is less than that of shipping protein via another, say pork, then the families might consume the same protein but through different diets. Furthermore, location is an endogenous factor. People live in areas where they can capitalize on their advantages in production; so it could be that the "alike in all other respects" begs the more important issue of how some families end up on the farm and others in the city.

[11]Although not the direct comparison our example suggests, the detailed descriptions of midwestern farm diets in Craig (1993) and those of British workers in Clark, et al. (1995) illustrate the contrast. Antebellum midwestern farmers probably consumed twice the calories and protein of the British workers.

[12]In a related study, Margo and Steckel (1983) report that antebellum farmers were taller than nonfarmers, but Costa (1993) finds after controlling for father's occupation, farmers were no taller than non-farmers; thus, she concludes that "the height advantage of farmers results from the characteristics of the environment they grew up in" (p. 368).

important than family income in determining heights. Of course spending infancy in a community that generated an agricultural surplus would not ensure that one had access to the resulting nutrients, nor would residence in a community that imported nutrients from another locale necessarily imply that one's consumption was deficient in any sense. Other economic variables would play some part.

As we noted above, wealth could be employed to purchase nutrients produced in another locale, and assuming that nutrition is a normal good, greater wealth would be expected to be spent, at least partly, on nutrition.[13]

Furthermore, it is net rather than gross nutrition that determines stature, and contraction of disease tends to reduce net nutrients and thus lower height. Since residence in an urban area would have increased the probability of contracting a communicable disease, the extent of urbanization played a negative role in stature by reducing net nutrition, *ceteris paribus*. In addition, as suggested above, nutrients were more expensive, especially relative to other products, in urban areas than rural areas.

Finally, since the relationship between local nutrient production, relative prices, and adult height, hinges on the costs of transporting foodstuffs from the farm to some other location, access to lower cost transportation in deficit areas would have led to a lower relative price of nutrients, greater consumption, and thus greater stature. Conversely, in surplus areas, reduced transport costs would raise the net price to farmers and encourage additional production of nutrients; however, it might also increase the export of nutrients from the area. Lower

[13]Stone's famous study of British consumption showed the income elasticity of basic food groups to between 0.5 and 1.0, and more recent estimates confirm this range, see Stone (1954).

transportation costs would also reduce the costs of imported merchandise and might have induced farmers to substitute (urban) manufactured goods for home manufactured ones, and to the extent they did so, farmers could have increased the production of nutrients for export. In other words, in surplus areas reduced transportation costs may not have resulted in greater stature. Finally, exposure to disease might also be associated with access to trans-regional transportation networks; thus it is not easy to predict the net effect of transportation access on local nutrition and stature.

3. Data

The discussion in the previous sections suggests that the biological relationship between the net consumption of nutrients in infancy and adult height, and the economic relationship between the local production of nutrients and economic well being represented by adult height, can be tested by matching adult height with economic conditions in the location in which an individual was born. In order to conduct this test, we have matched the adult height of two samples of Union Army recruits with a combination of personal variables and variables that reflect the economic environment of the locale in which the individual spent infancy.[14] We estimate the key relationships with the following equation:

$$HEIGHT = \alpha + \beta_1 MOVER + \sum_{j=1862}^{1865} \beta_{2j} YEAR_J + \beta_3 NUTRITION + \beta_4 WEALTH + \beta_5 TRANSPORT + \beta_6 URBAN + \varepsilon \qquad (5)$$

[14]While there is obviously variation among individuals within a genetic "pool", and while a father's height might explain his son's height, the Union Army was composed of descendants from a single genetic pool, and so there is no reason to expect systematic variation in heights by country of origin (Steckel, 1995, p. 1910).

where HEIGHT is the height in inches of the *ith* Union Army recruit. MOVER is a dummy variable, which takes the value 1 if the recruit enlisted in a county other than the one in which he was born, 0 otherwise. $YEAR_j$ is 1 if the recruit enlisted in the *jth* year, 0 otherwise. We have constructed two different measures of NUTRITION: PROTEIN is the marketable surplus of protein production in the county in which the recruit spent infancy, and CALORIES is the surplus in calorie production. WEALTH is the sum of agricultural and industrial wealth per capita in the recruit's county. TRANSPORT is 1 if the county was on a navigable waterway, 0 otherwise. URBAN is the proportion of the county's population living in an urban area. For quick reference, Table 1 contains a brief description of each of these variables, and the means and standard deviations are reported in Table 2.[15]

Our sample of white recruits is from the data collected by Fogel, Engerman, et al. and includes all recruits born between 1838 and 1842 for whom information was available on county of birth, county of enlistment, and adult height. The recruits who passed this test were matched with data reflecting economic conditions in 1840 in their county of birth; this process yielded 4363 matches. Obviously, we would have liked to have had annual economic data for each county to match with the infancy of each recruit, but in the absence of such data we relied on those collected by the U.S. census of 1840. Of course, agricultural production varied from year to year, and so using production figures from 1840 as the foundation of access to nutrients for a recruit who was born in some other year around that benchmark is not the ideal choice.

[15] In our regression for black recruits we also used a dummy variable for cotton production, COTTON, which is 1 if a county was one of Gray's "cotton" counties, 0 otherwise. This variable is intended to reflect the effect of the favorable world terms of trade in cotton during the antebellum era.

For those born before 1840, local deviations from long-run means would have been random and by increasing the standard errors of the resulting estimates would tend to bias against falsely rejecting the null hypothesis that net nutrition did not affect stature. With respect to recruits born after 1840, if 1840 were an unusually productive year locally, then as both Gallman (1996) and Komlos (1996) note, storage, although not well recorded, would have tended to convey surpluses into the next season or two, thus still affecting infants born after the 1840 crop year. If 1840 were an unusually bad year, then at the margin some families would have faced an increase in the relative price of nutrients and either depleted their wealth or altered consumption bundles accordingly, thus affecting the nutrition of infants born in the following year.

We also identified the county in which a recruit enlisted and used that to gauge the impact of a recruit's having moved. Although we know the county in which the recruit was born, we can not be certain that he spent his childhood in the same county. Nevertheless, it seems reasonable to assume that recruits for whom the county of birth was the same as the county of enlistment had a substantially higher probability of spending infancy in their county of birth. We refer to these recruits as "stayers;" the others are "movers". The coefficient corresponding to the dummy variable MOVER reflects the difference between movers and stayers - that is, between those who probably spent their entire formative years in one location and those who did not. The sign of this effect could be positive or negative. The statistics in Table 3 on the mean heights of recruits in various groups indicates that movers were on average taller than stayers. This suggests moving may have been self-selecting activity for more ambitious individuals and families.[16] The

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[16] Galenson and Pope found that the mean wealth for "persisters" was greater than "nonpersisters" in every age category (Galenson and Pope, 1989, p. 644), although they also concluded that "Very high levels of economic opportunity may have been a characteristic of the farming frontier (p. 635)."

economic advantages of moving might have yielded nutritional advantages for the children in those families that moved, and so the expected sign of the coefficient would be positive. On the other hand, the coefficient could be negative if stayers remained where they were born because they were successful there relative to those who moved or because they stayed in relatively bountiful areas.

We also included a set of dummy variables for enlistment $YEAR_j$. The policies of the Union Army administration, which themselves were a response to the situation on the battlefield, resulted over time in the minimum height for new recruits being lowered. Fred Shannon discusses the army policies in some detail and notes that "... the greater freedom of selection in the later drafts is shown in the diminishing minimum height requirement during the war (1928, vol. 2, p. 123)." So we would expect that the yearly dummies would have negative signs and possibly get larger in absolute value over time.[17] Table 3 compares the mean height of recruits inducted in each year with the mean from the previous year. In no year did the mean get larger, and in two of the four years, the recruits were on average shorter than those from the previous year.

The effects on heights that interest us the most are those that result from measures of net protein production in the recruit's county of infancy.[18] The data for the calculation of these

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[17]In response to this and other problems relating to the truncation of the data, we omitted all observations for which the recruit was less than 62 inches and then re-estimated equation (5). Although the truncation suggests regression techniques other than OLS might be warranted, research on this sample conducted at the Munich Seminar in Economic History indicates little difference between the results obtained with these techniques and with OLS.

[18] We used net production rather than gross because it nets out the effect of differences in the composition of the population, and because it more closely approximates the marketable surplus and was thus more subject to the market forces we think influenced the outcomes.

variables were collected by the authors from the published volumes of the Sixth Census of the United States.[19] After we obtained the matrix of farm output for each county in the United States in 1840, we converted that matrix into two vectors of nutrition - one containing grams of protein and the other calories.[20] We then subtracted mean human and livestock requirements from those figures.[21] The resulting vectors represent the marketable surpluses of protein and calories for every county in the United States in 1840, and we matched those figures with each recruit's height by county of birth. In equation (5) b_3 captures the effect on adult height of having had access to net nutrition in infancy. The literature discussed in Section 1 in combination with the model presented in Section 2 suggests that this effect should be positive. Table 3 shows the average recruit from counties that produced a net surplus of protein was more than an inch taller than his counterpart from a deficit county, suggesting a correlation between the local production of nutrients and adult stature.

The Sixth U.S. Census (1840) does not contain information on household wealth. Of necessity we have used the sum of the value of agricultural and manufacturing assets per capita

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[19] We had to estimate the output of a number of important products that were omitted from the Sixth Census. See our forthcoming paper (Craig and Weiss, 1997) for details.

[20] These conversions were two-step processes. First, we converted the physical quantities to weight using the information provided by Lipton (1995, Appendix 7). Second, we converted weight into grams of protein and energy (kcals) using the conversion rates in Ensminger et al. (1994, table P-37).

[21] Considerable debate surrounds such estimates for the 19th century United States, particularly regarding consumption by humans. The results reported below are from a "moderate" set of estimates which lie between upper and lower bounds derived from figures supplied by Gallman (1996) and Komlos (1996). Using Komlos's figures of 3,882 and 2,700 (k)calories per day as upper and lower bounds for adult males and his estimate that adult males on average consumed 20 percent more calories than the population as a whole as guidelines, our "moderate" consumption estimates are as follows: adult males=3,300 calories, adult females and teenagers=2,700, and children=1000. The estimates of consumption by livestock come from Atack and Bateman (1987, p. 210) with some revisions in Craig (1993, Appendix A). It is worth noting that although the size and statistical significance of the coefficients in equation (5) varied between Komlos's upper and lower bound estimates, qualitatively the results differed little.

that were reported in the Seventh Census for 1850 as our measure of local wealth. Based on the observation that wealth tends to be an autoregressive process, we are assuming that a county that was relatively wealthy in 1850 was also relatively wealthy in 1840.[22] As we argued above, access to nutrition must have been related to income and wealth, and so we expect the coefficient on WEALTH, b_4, to be positive. The evidence in Table 3 support this hypothesis. As mean per capita wealth in the county of birth increased, the recruits' average adult height increased as well.

The dummy variable for transportation, TRANSPORT, is included to capture the possible effects from being located near the regional transportation network. This variable was first constructed and employed by Craig, et al. (forthcoming) to capture the effects of transportation improvements on land values. In 1840, this network was primarily composed of rivers, canals, lakes, and the Atlantic Ocean. Living in a county with access to regional and international transportation networks had potentially conflicting effects on nutrition and height.[23] On the one hand transportation access would have lowered the cost of obtaining nutrition, suggesting the coefficient on TRANSPORT, b_5, would be positive; however, transportation facilitated the movement of nutrients *out* of a surplus region. Furthermore, transportation facilitated the movement of people and hence disease as well as goods, which would have reduced net nutrition. Therefore, the predicted sign of b_5, is ambiguous. It is worth noting that Table 3 shows that on average recruits from counties without access to transportation were taller than those with access.

[22]For 1518 counties matched between 1850 and 1860 by Craig, et al. (forthcoming) the correlation coefficient for wealth was 0.93.

[23]Because of the strong correlation between counties with ports located on the Great Lakes or Atlantic coast and the URBAN variable, the TRANSPORT variable is restricted to canals and navigable rivers.

Finally, we have included the share of the population residing in an urban area in the recruit's county of birth to capture the disamenities of urban life, particularly exposure to disease.[24] As we noted above, disease places demands on nutrition; exposure to disease was likely to be negatively correlated with net nutrition. After controlling for wealth and access to transportation, we expect b_6, the coefficient on URBAN to be negative. The data in Table 3 support this hypothesis, with mean adult height declining with urbanization in the recruits' county of birth.

4. Results

The results from estimating equation (5) for the sample of white Union Army recruits are reported in Table 4. The first two columns contain the results from estimating the full sample; whereas columns 3 and 4 contain a truncated sample - that is, only those recruits who were at least 62 inches in height. The regressions reported in columns 1 and 3 employ net protein production as the nutrition variable, while columns 2 and 4 report the results from using net calorie production.

In every specification, the nutrition variables are positive and statistically significant. Since the results for the two samples do not differ substantially, our discussion focuses on the full sample. Our protein variable is measured in hundreds of grams per capita per day; so, the coefficient in column 1 indicates that individuals who spent infancy in a county that produced a net protein surplus one standard deviation above the mean would have been on average one-tenth

[24]The creation of the urban share variable is discussed in Craig and Weiss (1996).

of one inch taller as an adult, *ceteris paribus*, than those from the mean county.[25] Similarly, a surplus of one standard deviation above the mean in calorie production yielded an additional one-fifth of an inch in adult height.[26]

It is worth reiterating that these results reflect potential access to nutrition rather than actual consumption; the standard deviation in the example above pertains to the per capita production of net nutrition in the recruit's county of infancy not in per capita consumption. Our results suggest, however, that in surplus counties at least some of the surplus found its way proportionally to infants, and conversely in deficit counties, some of the economic costs were borne by the infants.[27]

The other variables seem to be generally consistent with the expectations generated from the literature and our model.[28] The size of the coefficient on wealth indicates that a $100 increase in per capita wealth (about one standard deviation) in the county of infancy would increase adult height by roughly two-tenths of an inch. Again it is well to remember that this is

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[25] A protein surplus of one standard deviation above the mean would have been the same as roughly 70 grams of additional protein per capita - 10 ounces of pork or 1.5 pounds of whole wheat bread (Ensminger, et al., 1994, table P-37). By any measure, these would be substantial additions to the average antebellum diet. More to the point, since we do not know how much any individual was able to augment his diet, these figures suggest the abundance of nutrition that was available to recruits in such surplus-producing counties.

[26] Baten (1996a and 1996b) found that milk production had a substantial effect on nutritional status in nineteenth century Germany. We added separately the proportion of net nutrients obtained from milk and animal sources to the specifications reported in Table 3 and found no statistically significant effect from either variable.

[27] The allocation of the surplus within the household is an important topic but beyond the scope of this paper. In order for that issue to substantially impinge on our interpretation of the results in Table 4, however, it would have to be the case that the distribution of the surplus, or the burdens of any deficit did not vary systematically with the size of the surplus or deficit.

[28]For example, Costa (1993, pp. 363-69) reports similar effects, at least qualitatively, for the enlistment year dummies, a dummy for living in a *rural* area, and various indicators of wealth.

the increased wealth for the county as a whole. We do not know how well the recruit's family fared. The effect we are measuring then captures the combined impact of higher levels of wealth as well as the effect of differences in its distribution. Being born in a county with a larger urban population had a detrimental effect on adult height, but the impact is noticeable only when urban share varies by a relatively large proportion. For example for every 25 percentage point increase in the urban share of the population, adult height would have been reduced by slightly less than one-tenth of an inch. The transportation access variable had no statistically significant effect on height in three of the four models, and the coefficient was negative in each, offering moderate support for the idea that either disease or incentives to ship nutrients out overwhelmed the effects of lower cost nutrients.

With respect to the variables pertaining to the individual rather than the county in which he was born, moving from the county in which you were born had a large positive, and statistically significant, effect on adult height - those who enlisted in a county other than the one in which they were born were on average four-tenths of an inch taller than those who enlisted in the county in which they were born. As we noted above, this result could not have been unambiguously predicted, although the raw data in Table 3 suggested it.[29] It would seem to indicate that movers were relatively better able to obtain nutrients when they were young. Perhaps this finding is indicative of their parents' success and ability to finance the movement of their families, or perhaps individuals and families that were relatively well fed and healthy were more inclined to be adventurous, or perhaps they simply moved to more bountiful counties.

[29] Costa (1993, table 4, p. 364) using a much smaller sample composed entirely of recruits from rural areas found that movers were on average *shorter* than stayers.

Finally, the dummy variables denoting year of enlistment were negative, as expected, and by the last year of the war, the effect was quite large, with the 1865 recruits being on average nearly an inch shorter than those who enlisted before 1862.

We also tested the hypothesis that local nutritional surpluses were correlated with the heights of blacks. We used a sample of black Union Army recruits who were largely former slaves and a slightly different version of equation (5). The black data set was constructed in essentially the same way as the white sample with the exception that the dummy variable for recruits who remained in their county of birth could not be reliably constructed for the blacks.[30] In addition, we added a dummy variable for cotton counties to see if the relative value of cotton translated into nutritional gains for slaves. We ran separate regressions for black and white recruits because of the extensive literature indicating that slaves' diets differed substantially from those of free whites.[31] The literature on the nutrition of slaves indicates that the growth of slave children was stunted until they began to work, after which time they "caught up" in growth during adolescence. If this were the case, then slave feeding regimes would differ from those of whites. In particular surpluses would not translate into better diets for slave infants. Indeed, if slaves were a quasi-fixed factor of production then one would expect the costs of maintenance to be viewed by the owner similarly and thus vary little, if at all, with the local production of nutrition.

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[30]The original data on black Union Army recruits were collected by Metzer and Margo. Unfortunately, the codes they used for the counties of birth and enlistment were not the same as those used by ICPSR or Fogel and Engerman et al. So, we could not create the same county dummy variable for the slaves as we had for whites.

[31]Komlos (1992) and Steckel (1995) review the literature on slave diets and the resulting pattern of growth and development.

Table 5 contains the results for the black recruits. The difference in the results is quite striking, particularly the effect of the nutrition variables on height. The signs of all the coefficients are negative. For protein, there was no statistically significant effect on height, but in the case of calories the coefficients are statistically significant and negative. A decrease in net calorie production of one standard deviation below the mean yielded an increase in the heights of black adults of roughly one-tenth of an inch.

Although the negative relationship between surpluses and height for the black recruits may appear anomalous at first glance, it is in fact the effect predicted by Coclanis, et al. (1995). They argue that a decrease in the relative price of nutrition would have led to a substitution out of the production of nutrition and into other goods (like cotton, sugar, and tobacco), the long-run terms of trade of which were more favorable than those of food. This shift would have increased the marginal productivity of slaves, making them more valuable to owners who would have protected their investments by improving slave diets; thus a decline in food production would have led to an increase in slave consumption of nutrition and in their heights.[32] Although not without controversy, since it runs counter to the evidence that plantations were self-sufficient in foodstuffs,[33] their model is at least consistent with the body of literature that suggests the nutrition regimes of slaves differed substantially from those of whites.[34] Specifically, as the price of slaves rose relative to that of food, slave owners were more likely to supply slaves with more nutrition.

[32]This reasoning may also explain the strong negative effect of transportation access on the adult heights of black recruits. Slaves shouldered all of the negative aspects of such access, such as exposure to disease, without necessarily obtaining any of the concurrent gains.

[33]See, for example, Gallman (1970) and Ransom and Sutch (1977).

[34]Komlos (1992) contains a summary of the issues and literature.

5. Conclusion

Although we issued a number of caveats concerning our data and the interpretation of our results, the economic significance of the results is quite interesting. First, we have presented one of the few studies that matched at the individual level a biological measure of the standard of living (adult height) with the local measures of economic activity in the location in which the individual spent infancy. For free whites, our results confirm the hypothesis that access to nutrition contributed to economic well-being as manifested in adult height. A key here is of course *access*; we do not yet know that these individuals actually consumed the surplus that was produced. Second, our results illustrate, using biological measures, another aspect of the difference between slaves and free whites. Nutritional surpluses did not find their way into the stomachs of slaves residing in the county that produced the surplus. Our results confirm earlier work that suggests the slave feeding regime, while responsive to economic signals, did not adjust in the same manner as that of free whites.

Our results also contribute to the debate on the standard of living. By directly linking the local production of nutrition and adult height, they strengthen the connection between output, relative prices, and biological measures of the standard of living. Of course, since our sample is of a cross-section of individuals, our results do not directly contribute to the standard of living debate; however, if relative prices matter across locales, then it is not difficult to imagine that they affect behavior over time as well.[35]

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[35] It may also be possible in certain situations, such as low levels of income and consumption, to use our results to infer information about the level of agricultural output from information on heights. Such exercises must be conducted with much care. See Steckel (1995, p. 1916) for a discussion of the problems and pitfalls in pursuing this line of work.

Finally, our evidence on the correlation between county-level nutritional surpluses in infancy and increased stature in adulthood brings to the fore the economic decision making that may or may not have channeled those surpluses into consumption by the residents of the county. As agricultural output increased and as transportation improvements tied that output to world markets, individual farm households were faced with both changing relative prices and constraints, and the question of exactly how the resulting surpluses, which subsequently manifested themselves in the stature of adults, were allocated within the local households remains to be answered.

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might be an avenue to explore for countries, regions, and periods, for which data on heights are available but data on production are not.

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Table 1. Variable names and definitions

Variable	Definition
Variables for individual recruits:	
HEIGHT	Height in inches
MOVER	1 if the recruit enlisted in different county than the one in which he was born, 0 otherwise
YEAR186*i*	1 if the recruit enlisted in 186*i*, 0 otherwise
Variables from the county in which the recruit was born:	
PROTEIN	Surplus protein production (100s of grams per capita per day)
CALORIES	Surplus calorie production (1000s of kcals per capita per day)
WEALTH	Value of agricultural land and implements and manufacturing wealth (per capita)
TRANSPORT	1 if the county was on a navigable waterway, 0 otherwise
URBAN	Proportion of a county's population residing in an urban area
COTTON	1 if county was one of Gray's "cotton" counties, 0 otherwise (black recruits only)

Note: The text contains the description and sources of each variable.

Table 2. Variable means and standard deviations

Variable	Mean	Standard Deviation
*Variables for individual **white** recruits:*		
HEIGHT	67.44	2.61
MOVER	0.58	0.49
YEAR1862	0.44	0.50
YEAR1863	0.07	0.25
YEAR1864	0.21	0.41
YEAR1865	0.09	0.29
*Variables from the county in which the **white** recruit was born:*		
PROTEIN(x100)	0.91	0.71
CALORIES(x1000)	6.71	4.33
WEALTH	216.29	96.35
TRANSPORT	0.59	0.49
URBAN	0.27	0.54
COTTON	-	-
*Variables for individual **black** recruits:*		
HEIGHT	66.97	2.64
MOVER	-	-
YEAR1862	-	-
YEAR1863	0.33	0.30
YEAR1864	0.66	0.47
YEAR1865	0.01	0.11
*Variables from the county in which the **black** recruit was born:*		
PROTEIN (x100)	1.65	1.08
CALORIES(x1000)	15.00	4.51
WEALTH	255.88	122.66
TRANSPORT	0.30	0.46
URBAN	0.03	0.11
COTTON	0.01	0.08

Table 3. Mean height in inches by various groups of recruits

Variable	Number of Observations	Mean	Standard Deviation	t-stat
"MOVER"	2517	67.59	2.56	-
"STAYER"	1846	67.23	2.65	4.42***
Enlistment Year:				
1861	854	67.68	2.81	-
1862	1915	67.58	2.54	0.90
1863	289	67.16	2.75	2.43***
1864	902	67.32	2.51	-0.87
1865	403	66.75	2.44	3.82***
County with a Nutritional:				
Surplus	3985	67.54	2.60	-
Deficit	378	66.34	2.46	9.02***
County with:				
WEALTH≤$100	506	66.60	2.64	-
$100<WEALTH≤$250	2063	67.43	2.58	6.35***
$250<WEALTH	1794	67.69	2.58	3.17***
TRANSPORT=1	2584	67.35	2.58	-
TRANSPORT=0	1779	67.56	2.65	-2.55***
County with:				
URBAN≤5%	2263	67.76	2.59	-
5%<URBAN≤25%	802	67.59	2.54	-1.67**
25%<URBAN≤50%	391	67.14	2.52	-2.84***
50%<URBAN	907	66.62	2.57	-3.39***

Notes: The t-statistic was calculated to test the hypothesis that the mean height of the individuals in that group differed from that of the group immediately above it.

**The probability of obtaining a t-statistic this large when the null hypothesis that $m_i=m_j$ is true is less than 0.05.

***The probability of obtaining a t-statistic this large when the null hypothesis that $m_i=m_j$ is true is less than 0.01.

Table 4. Regression Results for White Recruits

Variable	Full Sample (1)	(2)	Truncated Sample (3)	(4)
INTERCEPT	67.08***	66.95***	67.36***	67.24***
	(0.15)	(0.15)	(0.14)	(0.14)
Variables for individual recruits:				
MOVER	0.408***	0.402***	0.369***	0.370***
	(0.081)	(0.081)	(0.077)	(0.077)
YEAR1862	-0.139	-0.149	-0.215	-0.225**
	(0.081)	(0.105)	(0.101)	(0.100)
YEAR1863	-0.539**	-0.528**	-0.541**	-0.531**
	(0.081)	(0.175)	(0.167)	(0.166)
YEAR1864	-0.464***	-0.470***	-0.517***	-0.525***
	(0.141)	(0.122)	(0.116)	(0.116)
YEAR1865	-0.996***	-0.997***	-0.971***	-0.973***
	(0.528)	(0.155)	(0.148)	(0.148)
Variables from the county in which the recruit was born:				
PROTEIN	0.1408**	-	0.1190**	-
	(0.0629)		(0.0593)	
CALORIES	-	0.0470***	-	0.0424***
		(0.0107)		(0.0101)
WEALTH	0.0020***	0.0016***	0.0018***	0.0014***
	(0.0005)	(0.0005)	(0.0004)	(0.0004)
TRANSPORT	-0.0833	-0.0755	-0.1301*	-0.1226
	(0.0803)	(0.0800)	(0.0762)	(0.0759)
URBAN	-0.3772***	-0.3008***	-0.3260***	-0.2550***
	(0.0786)	(0.0809)	(0.0747)	(0.0769)
COTTON	-	-	-	-
R^2(adj)	0.04	0.04	0.04	0.04
F	20.02***	21.67***	18.26**	19.83***
N	4363	4363	4270	4270

Table 5. Regression Results for Black Recruits

Variable	Full Sample (1)	(2)	Truncated Sample (3)	(4)
INTERCEPT	67.44***	67.73***	67.62***	67.91***
	(0.18)	(0.27)	(0.17)	(0.25)
Variables for individual recruits:				
MOVER	-	-	-	-
YEAR1862	-	-	-	-
YEAR1863	-	-	-	-
YEAR1864	-0.421	-0.072	0.061	0.025
	(0.141)	(0.141)	(0.131)	(0.131)
YEAR1865	0.172	0.166	0.184	0.176
	(0.528)	(0.528)	(0.493)	(0.493)
Variables from the county in which the recruit was born:				
PROTEIN	-0.0703	-	-0.0539	-
	(0.0572)		(0.0534)	
CALORIES	-	-0.0280*	-	-0.0256*
		(0.0147)		(0.0137)
WEALTH	-0.0007	-0.0005	-0.0009	-0.0007
	(0.0005)	(0.0006)	(0.0005)	(0.0005)
TRANSPORT	-0.4663**	-0.4796***	-0.4342***	-0.4621***
	(0.1381)	(0.1376)	(0.1295)	(0.1290)
URBAN	-0.6733	-0.9275*	-0.7095	-0.9664*
	(0.5444)	(0.5711)	(0.5100)	(0.5348)
COTTON	0.3118	0.3754	0.1043	0.1573
	(0.7175)	(0.7167)	(0.6585)	(0.6577)
R^2(adj)	0.01	0.01	0.01	0.01
F	2.45**	2.78***	2.65**	3.00***
N	2141	2141	2058	2058

Notes to Tables 4 and 5:

Standard errors are in parentheses.

*The probability of obtaining a coefficient this large when the null hypothesis that $b_i=0$ is true is less than 0.10.

**The probability of obtaining a coefficient this large when the null hypothesis that $b_i=0$ is true is less than 0.05.

***The probability of obtaining a coefficient this large when the null hypothesis that $b_i=0$ is true is less than 0.01.