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Working Paper 10993
http://www.nber.org/papers/w10993

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
December 2004

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NBER Working Paper No. 10993
December 2004
JEL No. N3, I1

ABSTRACT

For over a quarter century anthropometric historians have struggled to identify and measure the numerous factors that affect adult stature, which depends upon diet, disease and physical activity from conception to maturity. I simplify this complex problem by assessing nutritional status in a particular year using synthetic longitudinal data created from measurements of children born in the same year but measured at adjacent ages, which are abundantly available from 28,000 slave manifests housed at the National Archives. I link this evidence with annual measures of economic conditions and new measures of the disease environment to test hypotheses of slave owner behavior. Height-by-age profiles furnish clear evidence that owners substantially managed slave health. The short-term evidence shows that weather affected growth via exposure to pathogens and that owners modified net nutrition in response to sustained price signals.

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For over a quarter century economic historians have examined the profusion of data on stature for insights into the quality of life since the eighteenth century. Their study of muster rolls, slave manifests, convict records and other sources provides valuable knowledge of biological inequality, slavery, health aspects of living standards during industrialization, the relative health of men and women, the mortality transition, and many other subjects.[1]

Much research has gone forward using average adult stature, which summarizes the nutritional status of a population from conception to maturity. This summary aspect of adult height creates a double-edged sword: it broadly encompasses and distills numerous forces such as diet, disease and work effort, which significantly affect the quality of life. On the other hand, analysis of such evidence is complicated by the many factors that can influence a person's adult height over a time span of nearly two decades, from conception to maturity. Thus it is often difficult if not impossible to identify the specific causes that distinguish the average height of one birth cohort from another. Indeed, different cohorts may have identical average heights but for somewhat different reasons, such as relatively small size at birth in one group that is offset by good adolescent net nutrition in the other. Therefore any researcher of average adult height potentially faces a host of identification issues not unlike those involved in the study of national income, a summary measure of social performance that has inspired countless economic models specifying the pathways or mechanisms underlying outcomes.

This paper formulates a new technique for tackling the identification problem: synthetic longitudinal data. The method relies on the heights of growing children, which were abundantly recorded for antebellum American slaves, but the method can be applied to any population having height-by age data for individuals who had not reached maturity. By shrinking the time span of the health measure from nearly two decades to one year, it becomes feasible to link outcomes with forces that operated in that year.

The next section briefly describes an enlarged sample of over 28,000 slave manifests and compares height-by-age results with earlier research on slave stature. The main contribution of substance on the topic of slavery, pursued in the remainder of the paper, involves short versus long-term strategies of plantation management. At one end of the continuum of opinion, represented by Eugene Genovese's *The Political Economy of Slavery*, plantation owners were pre-capitalist, quasi-aristocratic landowners imbued with an antibourgeois spirit who most probably relied on tradition and rules of thumb to guide their farms.[2] Obtuse to profits but sensitive to norms of southern society, these planters avidly organized social events, were attentive to fashion, contributed to political discourse and orchestrated the marriages of their offspring but responded little to changing economic conditions in organizing production. A contrary hypothesis, put forward in *Time on the Cross*, envisions slave owners quickly adapting to prices of inputs and outputs in choosing to purchase or clear land, to hire or sell slaves, to change the crop mix.[3] Although not discussed in the book, presumably this alacrity also applied to components of net nutrition under planter control, including diet and work effort. I link the synthetic longitudinal height data with prices of inputs and outputs, controlling for weather and for epidemics, to assess the extent to which plantation owners responded to short run economic conditions in deliberately managing the health of their chattel.

Evidence

The Bill for the Abolition of the Slave Trade, passed by Congress in 1807, outlawed imports from Africa but permitted the coastwise trade to continue as a monitored activity.[4] Ship captains at the port of origin prepared duplicate manifests that described each slave by name, age, sex, height and color. One copy remained at the port of origin and the captain delivered the other to the port of destination, where the collector prevented smuggling by checking the cargo against the manifest.

Previous articles on slave heights used samples that were small or modest in size, which limited the options for chronological analysis within regions. Steckel's 1979 sample had 1,442 manifests involving 16,099 slaves, an effort subsequently enlarged to 10,562 manifests and 50,606 individuals.[5] This paper nearly triples the sample size, collecting all the manifests available at the National Archives in Record Group 36, which after eliminating a small number of duplicates, includes 27,580 manifests and 146,168 slaves.

Table 1 shows that slave origins were widely distributed around the Atlantic and Gulf coasts. Virginia provided nearly one-quarter of all slaves in the collection, followed by Louisiana (17.0%), South Carolina (15.6%), and Alabama (12.6%). The major ports within these states were Charleston, Norfolk, New Orleans, and Mobile. The geographic pattern of shipments tended to flow from east to west. Virginia, for example, provided 24.5 percent of slaves but received only 0.6 percent of the exports in the sample. At 14.0 percent, Georgia was the largest recipient of slaves on the Atlantic Coast but Louisiana was by far the most important destination (57.5%). New Orleans alone received 57 percent of all slaves.

Although the law became effective in 1808, only 8 manifests appear for the years 1808 to 1814. The War of 1812 no doubt interrupted shipments and many slaves in the early part of the westward migration probably traveled short distances overland, but the virtual nonexistence of records before 1815, the modest numbers before 1820, and the small number of exports from North Carolina over the entire period (a total of 558 slaves) suggest that some manifests did not survive to be lodged in the National Archives (see Table 2).[6] Shipments occurred in substantial numbers every year from 1818 to 1860 but the period of most intense activity took place from the mid 1840s through the mid 1850s. Nearly one third of all slaves were shipped between 1845 and 1854.

Even though the collection of manifests housed by the National Archives may be incomplete, there is no doubt that coastal shipments comprised an important share of westward migration. Comparing the manifests with estimates of the interregional movement of slaves prepared by Fogel and Engerman shows that nearly one slave in five who moved was listed on a manifest, and the ratio exceeded 25 percent during the decades of the 1820s and the 1840s.[7] Because most slaves who traveled from the interior states probably went over land, the coastal trade likely comprised a large share of all exports from the coastal states.

Growth depression of children and their remarkable recovery as teenagers have been at the center of height research on slave health. Comparisons with historical and contemporary populations show that American slave children were small in relation to children living in the poorest areas of least developed countries; such poorly nourished children would have elicited shock and alarm in a modern pediatrician's office.[8] On the other hand, the catch-up growth that American slaves witnessed as teenagers was remarkable if not unprecedented.[9] Overwhelmingly past and present populations that had very small children also had very small adults.[10] The slave pattern has numerous implications, not only for economic history and the understanding of the slave regime, but for biological processes of growth that interest anthropologists, human biologists, and nutritionists. The unusual pattern of physical growth strongly suggests that planters deliberately managed the health of slave children. The question addressed here is whether this management was fine tuned and extended to short-term control of net nutrition. The analysis below indicates that the answer is "yes."

The data in Table 3 make clear that the unusual pattern of physical growth was not an artifact of sample composition, whereby the slave trade mixed very short children from one region with tall adults from another. Growth depression and recovery prevailed within all regions, although its extent was somewhat less in the Chesapeake compared with lower states in the South. Several features of life are potential explanations for health that deteriorated with more southerly location, including a decline in dietary diversity, a harsher disease environment, and greater work effort on larger plantations organized by gang labor. The power of these explanations is under investigation.

The unusual age profile of slave growth is unlikely to have been caused by a disease environment that improved around age 10, approximately the age when children began working.[11] Indeed, the physical effort of work would have drained net nutrition, other things being equal. Thus it is very probable that the diet improved by more than enough to offset the drain of work. It is relevant to ponder whether this pattern was profitable. Through trial and error, or possibly more sophisticated calculations, did slave owners conclude they should starve children but feed working children enough for catch up growth? The answer is yes, based on the costs of pork and therefore protein, the most deficient item in the child diet, and the value of on inch of height. Even if mortality rates fell by 50 per cent and children were able to work beginning at age 8 with an improved diet, the rate of return on this investment was only 1.2 per cent,[12] which is far below the 10 per cent estimated by Fogel and Engerman for the rate of return on a slave purchase.[13] This result highlights the importance of the family in protecting the interests of children in free society.

Synthetic Longitudinal Data

Figure 1 depicts the growth velocity of American boys, tabulated from modern American growth standards, which illustrates the average pattern of growth under good conditions in the United States. Several studies confirm the similarity of this pattern across a wide range of well-nourished ethnic groups; children who grow up under good conditions are approximately the same height regardless of genetic heritage. Growth is clearly most rapid in early childhood and after several years of irregular decline children experience an adolescent growth spurt, which adds considerably to their eventual height as adults. The adolescent spurt and other aspects of physical maturation begins about 2 years earlier among girls than boys and primarily for this reason females end up about 4.5 inches shorter as adults, i.e. girls have about 2 years less growth at preadolescent rates. The general pattern of growth is not automatic, however, and is very sensitive to the environment. If poor conditions suddenly appear, children will cease to grow almost immediately. Nutritional stress during wartime demonstrates the vulnerability of children to adverse net nutrition.[14] In a phenomena know as "catch-up growth" children can rapidly recover some or possibly all lost ground if good times return. This feature of growth leads researchers to monitor the consequences of health or nutritional interventions by repeated (longitudinal) measurements.

Military organizations systematically recorded heights since the mid-eighteenth century and their archives provide an enormous reservoir of information for study of nutritional status from the eve of the industrial revolution onwards. Such data are enormously valuable because the measurements summarize net nutritional conditions from conception to maturity. Because all we have is the end result (adult height), however, we do not know when (at which age) various forces of diet, disease or work may have affected growth. This identification problem confounds the interpretation of adult height, but a solution can be extracted from the heights of those who were still growing.

Consider individual 1 in Figure 2, a slave child born in 1830 who was measured at age 5 and again at age 6. The growth of the child reflects net nutritional conditions during the year 1835, and with numerous measurements of this type for a variety of years, one could connect child growth in those years with changing environmental conditions. In this way one could assess the extent and rapidity with which slave owners modified diet and/or work effort in light of changing prices of food inputs and of product outputs.

Unfortunately the manifests do not record genuine longitudinal data. But they do report heights of children born in the same year and measured once at different ages, as demonstrated by individuals 2 and 3 in Figure 2. One can estimate net nutritional conditions in 1835 by subtracting the height of individual 2, measured at age 5 in 1835, from that of individual 3, measured at age 6 in 1836. Because they were both born in the same year, presumably they had similar nutritional experiences as a birth cohort (up to age 5), at least as affected by exogenous phenomena of prices, weather and epidemics.

Of course, individuals 2 and 3 may differ in their genetic potential for growth; conceivably the 3rd individual could have smaller in 1836 than the 2nd individual was in 1835, implying the impossible situation of negative growth. With large samples, however, these genetic features tend to cancel such that the difference in the mean heights accurately depicts average net nutritional conditions during the year.

Two adjustments or modifications of the procedure are needed to address limits of the manifest data. Despite the huge sample size overall, Table 3 shows that the number of children measured was rather small, especially below age 10. Therefore the number of measurements of children at adjacent ages in successive years is insufficient to obtain even remotely precise estimates of growth velocities for a particular age, sex and year. Aggregation by age and by sex overcomes this limitation, but to do this the results must be made comparable by standardizing for average growth velocity at a particular age and sex. Second, because the sample sizes vary considerably across ages (see Table 3), I then weight the standardized velocities by the relative sample sizes used to calculate the means. Equation (1) below defines the procedure:

$$I_{j,j+1} = \sum_{k=1}^{k=2} \sum_{i=3}^{i=16} \frac{\left(\bar{x}_{i+1,j+1,k} - \bar{x}_{i,j,k}\right)}{\bar{x}_{i+1,k} - \bar{x}_{i,k}} \left(w_{i,j,k}\right)(100) \qquad (1)$$

where $I_{j,j+1}$ is an index of growth velocity between years j and j+1, expressed as percent of average (across all years) for the entire collection of manifests. The indexes j and k are counters for age and sex, respectively, whereby velocities in a particular year are estimated as the differences between mean heights from ages 3-4 to ages 16-17. The term $w_{i,j,k}$ indicates the relative weight applied to the velocity at a particular age based on the sample sizes used in the calculations.[15] Thus, the weights for a particular year sum to 1.0.

Figure 3 shows the sample sizes used to calculate the index of growth velocity for a particular year, i.e. $n_j + {}_{j+1}$, where n_j refers to number of children of all ages and both sexes measured in year j. The numbers are modest in the 1820s and in some years thereafter, which raises a question for econometric methods. I deal with the varying sample sizes by using weighted least squares.

Two additional issues arise in the empirical work, one of which is chronological imprecision. Owners shipped slaves throughout the year but they concentrated departures in the 4 months from November to February. In principle one could utilize this chronological information in calculating velocities, by tabulating differences in mean heights by month of shipment, e.g. comparing average heights of slaves shipped in February of one year with those shipped 12 months later. The sample sizes are so small in a particular month, however, that this attempt at refinement is hardly worthwhile. Moreover captains reported the ages only as of last birthday as opposed to year and month, which would remain a factor limiting the accuracy of growth velocities in any case. In sum, the chronological synchronization problem creates so much noise in the yearly data that it is difficult to discern adjustments in plantation management within a single year. Providing there is enough variation over a somewhat longer time interval, it is still possible to examine sort-term modifications of decision-making. Therefore I smooth the dependent variable by using a 3-year moving average of the index of growth velocity, $I_{j,j+1}$.

Cropping patterns varied considerably between the upper and lower portions of the South. Tobacco, cotton, rice and sugar were the major field crops linked to various regions and across these areas slave owners responded to different price signals for outputs. This suggests the analysis should be organized by region of origin. Table 3 shows that by far the largest portion of the sample originated with the cotton producing areas, which stretched from North Carolina to Texas, with geographic interruptions for rice and sugar cultivation in coastal areas of South Carolina and Georgia and in southern Louisiana. Unfortunately little can be done to distinguish slave exports from rice versus cotton plantations in South Carolina and Georgia, and therefore I use all such manifests originating from these states. Rice was a small minority crop compared with cotton in the southern states and as a practical matter the inclusion in the database of slaves departing from rice plantations adds slightly to the noise in assessing the relationship between cotton prices and planter behavior.[16] Sugar was a growing industry throughout the period, largely absorbing rather than exporting slaves and for this reason the contamination from including Louisiana is probably small.[17]

Figure 4 displays a 3 year moving average of the velocity index for slaves exported from the cotton producing states along the Atlantic and Gulf coasts. Although the index fluctuates a great deal, two larger cycles are apparent: decline during the 1820s followed by recovery until the early-mid 1840s and then another decline followed by a recovery that began in the mid 1850s. Any simple but powerful explanation of short-term slave nutritional status would have to account for these two cycles. The data points in the figure form the dependent variable for the empirical model discussed below.

An Empirical Model

Rees, Komlos, Long and Woitek formulate a dynamic optimization model of food allocation over the slave life-cycle, in which owners maximize wealth in ways that explain two observed features of slave heights.[18] These features are the unusual age profile of physical growth and an increase in male slave heights during the late antebellum period.[19] The central variable explained in their model is field productivity (measured by stature), which they link to the prices of output (cotton), food, and slaves. Owners select optimal diets in light of these prices and the contribution food makes to human physical growth. Higher prices of cotton relative to food have an efficiency wage effect, encouraging owners to improve diets and therefore net nutrition and physical growth: slaves are better fed so they can work harder. Higher prices of slaves relative to food creates an investment incentive, whereby owners improve diets in the short run in anticipation of the greater value of future physical work capacity.

Rees et al. report that both male slave prices and cotton prices rose relative to food prices during the late antebellum period, which their mechanism translates into a prediction of increasing food allotments and physical growth. If the process they envision operated rapidly, then food allocations and therefore child growth would have responded quickly to increases in the ratio of slave prices to food prices, and with increases in the ratio of cotton prices to food prices. The authors do not model the speed of this mechanism, but with the data at hand it is possible to test whether it was rapid. A negative finding does not mean that the modeled mechanism did not exist, but only that it may have been slow or small in the short term.

Figure 5 displays the price ratio of cotton (New York) to pork (Cincinnati, mess) and the ratio of the price of prime age male slaves (New Orleans) to the price of pork.[20] Rees et al use prices of a more general market basket of food products to calibrate their model, but I feel that pork is the food item most relevant for an empirical test because it was the most expensive item in the slave diet, providing protein essential for human growth. Moreover, pork had high value in relation to weight and was therefore widely traded, making its market price a good proxy of opportunity cost on the farm.

Before considering empirical tests of the price-physical growth mechanism, it is useful to consider two additional factors that may have affected health and physical growth in the short term: weather and epidemics. In the past couple of decades climate historians have made considerable progress measuring annual aspects of weather using tree rings, which are sensitive to fluctuations in moisture. Climate historians have assembled long, overlapping series of tree rings for roughly 150 localities of the United States and they have distilled this information into something called the Palmer Drought Severity Index (PDSI).[21] They scale this index from -6 (very dry) to +6 (very wet) relative to normal for a particular locality. Figure 6 shows results in a 3 year moving average for 9 localities in the cotton states that exported most of the slaves used to calculate the velocity index. While moisture fluctuated considerably, there was a clear trend toward dryer conditions late in the antebellum period.

Moisture might have been relevant for health and physical growth in two ways, food production and exposure to disease. If it operated mainly through the former, one would expect to find a substantial connection with food prices. The correlations in Table 4 show this is not the case. Scatter diagrams and regressions also establish there is no statistically significant connection between the Palmer Index and the prices of pork or corn, at least within the range of weather conditions found across a swath of the South in the antebellum period.

Within the range of rainfall typically found in the cotton regions of the Southeast, roughly 45 to 50 inches per year from modern data, relatively wet conditions would have promoted the growth of parasites and insect vectors such as mosquitoes. In contrast, somewhat dry (but not drought) conditions would have reduced parasites and insect vectors but still provided adequate moisture for food production. If the antebellum record included extremes of the index, one might expect a nonlinear relationship, with bad health following from very wet conditions and also very dry conditions. Very wet weather would have been particularly bad because it created parasites and insects while reducing food production. Therefore it is important to consider the range of the index and to explore possible nonlinearities in the relationship between the Palmer Index and physical growth.

Cholera and yellow fever caused well-known epidemics in the antebellum era. According to Wilson Smille, cholera ravaged New Orleans in the early 1830s, was bad in the mid 1850s, and also appeared in the mid 1830s and the early 1840s.[22] Yellow fever was epidemic in the early 1820s, the late 1840s and the mid 1850s. The extent to which these epidemics penetrated into the rural interior of the South is unknown. One could argue that slaves in the sample could have been vulnerable because they were shipped from coastal ports and therefore may have been exposed, via regular trade contacts, to diseases that were notorious in the coastal cities.

Figure 7 shows a 3 year moving average of the average of the crude death rates in Baltimore and New Orleans, the high points of which indicate epidemic conditions in the South.[23] If conditions were bad it both cities, one might expect they were also bad along the coast in between, and possibly in the rural areas from which slaves were shipped Admittedly, these data are imperfect for study of the issues at hand, but it is clear the death rates fluctuated enormously. The cholera epidemic of 1832 is particularly pronounced. If under the worst conditions these diseases found their way into rural interiors along the coasts, then child growth would also have been affected.

Results

As indicated earlier, Rees et al. do not explain the speed of adjustment to changing economic conditions, which is a question to be examined empirically. Keep in mind that the dependent variable measures the standardized change in height from year y to year y+1, and the three year moving average centered on year y to y+1 incorporates change from year y-1 to year y+2.

One could argue that the time frame of the epidemiological variables should coincide with the dependent variable. An epidemic, for example, might register immediately in slower growth. On the other hand it may have taken time for an epidemic, observed in port cities, to penetrate the interior where most slaves lived. Similarly, a change in weather might precede changes in physical growth if insect and parasite vectors took time to accumulate (or disappear). Similar weather in successive years could have compounded the relationship, whereby the population of insect and parasite vectors and their infected (or uninfected) hosts was disproportionately magnified (or shrunk) by a sequence of wet (or dry) years. In the same vein, if there was inertia in plantation management, physical growth would have lagged behind relative price changes. It seems plausible that changes in food rations or work patterns, which were guided by price signals but appeared capricious to slaves, imposed psychological costs (i.e. labor unrest), and therefore owners would have changed routines only after a clear, persistent signal that it was profitable to do so. Thus, it may have been unprofitable to precisely synchronize the chronological relationship between relative prices and net nutrition.

Table 5 shows results from an exploration of the lag structure with all of the explanatory variables, ranging from coincident to a 3 year lag. Equations 1 – 4 indicate the best fit of simple regressions. Two results are anticipated: the large, systematic effects of the slave/pork price and the Palmer Index. The corresponding beta coefficients, which indicate the number of standard deviations of change in the dependent variable for a one standard deviation change in the independent variable are 0.48 and 0.72. With a lag that is one year shorter, the coefficients are still statistically significant but the t-values shrink to 2.37 and -3.05, respectively.

Most surprising is the large, but unexpectedly negative and statistically significant coefficient of the cotton/pork price. The coefficient is negative and statistically significant even without a lag. The theory predicts a positive coefficient. What might have happened? Conceivably planters adjusted in ways unanticipated by the theory, perhaps planting more cotton at higher relative prices (imposing more work or a different kind of work that required additional energy), without changing rations (because it was costly in terms of labor unrest). Thus slaves could have been less sensitive to changes in work routines than to changes in diet.

Equation 5 suggests a more plausible interpretation, which hinges on multicollinearity. The coefficient on cotton/pork is no longer significant in the presence of slave/pork and the Palmer Index variables. Although Table 4 shows that the correlation between the Palmer Index and the prices of cotton and pork was very low, by chance the correlation was much higher with cotton/pork price ratio, amounting to 0.72. I cannot think of a plausible mechanism by which the Palmer Index should have been highly correlated with the price ratio, and indeed by adding a few more years of evidence at the beginning of the period, the correlation drops dramatically to 0.06. Thus, the high correlation and consequent multicollinearity for the sample period is just bad luck. The cotton/pork coefficient has the wrong sign and by accident the variable represents or mimics the Palmer Index.

Multicollinearity may explain the statistical phenomena but the theoretical question remains: why didn't the cotton/pork price translate into net nutritional action by planters? Perhaps the effect existed but was simply small or swamped by other factors, and thus is not readily visible with the measures at hand. Notably the real price of slaves rose while the real price of cotton fell during the antebellum period. The real price of pork also rose, but the real price of slaves rose faster. Quite possibly the slave/pork price was a better indicator of profitability of net nutritional action than the cotton/pork price because the numerator of the latter was affected by technological change, westward movement to better land and the growth of large, more efficient plantations. In addition, the time horizon of the two variables is quite different, with the cotton price reflecting very short-term conditions whereas the slave price captured long run expectations of profitability. Thus, slave owners reacted to price information in deciding net nutrition but they focused through long-run lenses.

The average of the crude death rates in New Orleans and Baltimore had no systematic effect on the velocity index, regardless of the lag structure. This does not imply that epidemics were irrelevant for physical growth. Instead rural slaves were likely insulated from disease currents that dramatically appeared in the cities and along major travel routes. The health benefits of isolation are well documented for the era prior to the public health revolution of the late nineteenth century. In particular, average heights in different countries and across regions within countries are typically higher for remote, agricultural areas.[24]

In sum, equation 6 of Table 5 provides the most parsimonious model for explaining the short-term health of American slaves. The cotton/pork price and the crude death rate in cities were irrelevant for short-term health on southern farms, but in acting to manage the short-term health of their chattel, owners were subject to changes in the disease environment created by the weather. The latter was slightly more important in explaining variation in the antebellum period, based on relative sizes of the beta coefficients.

Is it possible to determine the amounts of diet and work that planters manipulated in modifying net nutrition? Were work routines relatively fixed and diets adjusted? Or were diets reasonably static but work routines varied? We lack detailed annual measures of diet and of work effort, and indeed the nature of these has been one of the ongoing controversies in the study of slavery. Thus, brute force methods are unavailable. But it is possible to divide the sample into two parts: younger (non-working) children and older children who worked. Presumably if control was achieved through diet alone, then the growth of young children would have responded to price signals. If through work alone, then the growth of older but not younger children would have responded to price signals. Of course, this is a weak test and it may well have been the case that owners manipulated both to their advantage. In any event and unfortunately, the annual samples of young children (ages 3 – 9 years) are too small for effective study given the noisy nature of the velocity index.[25] With the sample weights ($w_{i,j,k}$) of equation (1), the results in Table 5 are therefore by dominated by the experiences of working children (ages 10 and above), and with the data at hand it does not appear possible to form an empirically-based opinion on this issue.[26]

Conclusions

Since the mid 1970s economic historians have built upon the strengths and struggled with the weaknesses of adult heights. Powerful in summarizing many important factors relevant for the quality of life, these numerous variables unfold over many years, making it difficult to investigate short-term influences on the final result. Thus, adult heights are quite valuable as a measure of human welfare but it has been challenging to identify and measure the causes of changes or differences. Synthetic longitudinal data are a substantial step forward but remain an incomplete remedy. Researchers would still like to assess influences on the components of net nutrition within a year, or other short span of time.

Exposure to disease is one of the components of net nutrition typically found hard to measure, even in modern studies. This paper proposes the weather, as measured by the Palmer Drought Index, and the crude death rate, which reflects epidemics. Uncorrelated with agricultural prices, the Palmer Index most likely captures the density of insects and parasites that spread diseases. Researchers should be cautious in expecting the empirical success of this variable, and the failure of the crude death rate, to automatically translate into studies involving other regions or time periods. Effects of moisture on health may well depend on other features of climate. Of course, epidemics are relevant for health and human growth, but results of this paper suggest it may be difficult to interpret their geographic reach across rural societies.

All historians recognize the hard edges of slavery: the denial of freedom and genuine social mobility, the considerable possibilities for violence and brutality, and the psychological costs of the slave trade. Some influential historians, such as U.B. Phillips, have softened these edges with paternalism, or the notion that while life was generally hard in the early nineteenth century, owners had genuine feelings and emotional bonds with their chattel, and by implication planters were willing to sacrifice some profits for their happiness.[27] The height data tell a different story. Not only was the slave population deliberately made "peculiar" in its pattern of physical growth, owners were reasonably quick to manipulate net nutrition in light of changing economic circumstances. While there were traditional elements in diets and work, at the margins planters abandoned custom, and if physical growth and child health improved in the late antebellum period, it was because dryer weather reduced exposure to disease and owners expected a future economic pay back.

Table 1: Distribution of Slave Shipments by State

State	From (%)	To (%)
Maryland	8.92	0.59
Virginia	24.53	0.57
North Carolina	0.38	0.15
South Carolina	15.62	5.00
Georgia	10.22	13.98
Florida	5.22	3.99
Alabama	12.63	5.31
Mississippi	0.07	0.74
Louisiana	16.99	57.51
Texas	2.62	8.03
Unknown	2.78	4.14
Total	99.98	100.01

Source: Slave manifests. Number of slaves = 146, 168.

Table 2: Slave Shipments by Time Period

Date	Per cent
1808-14	0.0
1815-19	1.5
1820-24	8.0
1825-29	13.1
1830-34	9.0
1835-39	12.8
1840-44	11.7
1845-49	16.0
1850-54	16.0
1855-59	9.8
1860-63	0.9
Unknown	1.2
Total	100.0

Source: Slave manifests. Number of slaves = 146, 168.

Table 3: Percentile of Modern Height Standards Attained by Age, Sex and Region

	Males, ages					Females, ages				
Ports of Origin	3 – 4	5 – 9	10–14	15–19	23-49	3 – 4	5 – 9	10–14	15–19	23–49
Total	0.3	1.2	1.7	3.0	16.9	0.3	1.8	1.3	15.8	24.7
N	1,205	3,499	8,173	12,819	28,063	1,195	4,059	8,426	14,668	17,462
Md & Va	1.6	3.8	3.7	2.8	15.4	1.3	5.8	3.8	18.4	23.6
N	422	1,217	3,073	5,885	8,713	418	1,485	3,136	7,002	3,323
NC & SC	0.2	0.5	1.7	2.3	15.8	0.1	1.3	1.1	13.2	25.4
N	136	442	1,497	2,022	420	140	535	1,384	2,121	3,042
Ga & Fla	0.2	0.7	0.8	3.1	16.5	0.3	0.6	0.6	11.7	26.9
N	214	531	999	1,287	5,108	202	634	1,206	1,517	4,170
Ala & Miss	0.08	0.6	1.0	4.6	20.6	0.008	0.6	0.6	14.6	19.6
N	160	452	926	1,363	3,423	159	455	957	1,458	2,147
La & Tex	0.03	0.3	0.9	4.1	21.5	0.1	0.8	0.4	18.7	35.9
N	246	757	1,458	1,884	5,239	244	831	1,476	2,147	4,143

Source: Slave manifests and calculated from Steckel, "Percentiles of Modern Height Standards."

Table 4: Correlations among Dependent and Independent Variables

	Velocity Index	Slave Price	Cotton Price	Pork Price	Palmer Index	Death Rate
Velocity Index	1.000					
Slave Price	-0.092	1.000				
Cotton Price	-0.143	0.668	1.000			
Pork Price	0.050	0.678	0.418	1.000		
Palmer Index	-0.336	-0.024	0.067	0.267	1.000	
Death Rate	0.103	0.395	0.413	0.270	0.024	1.000

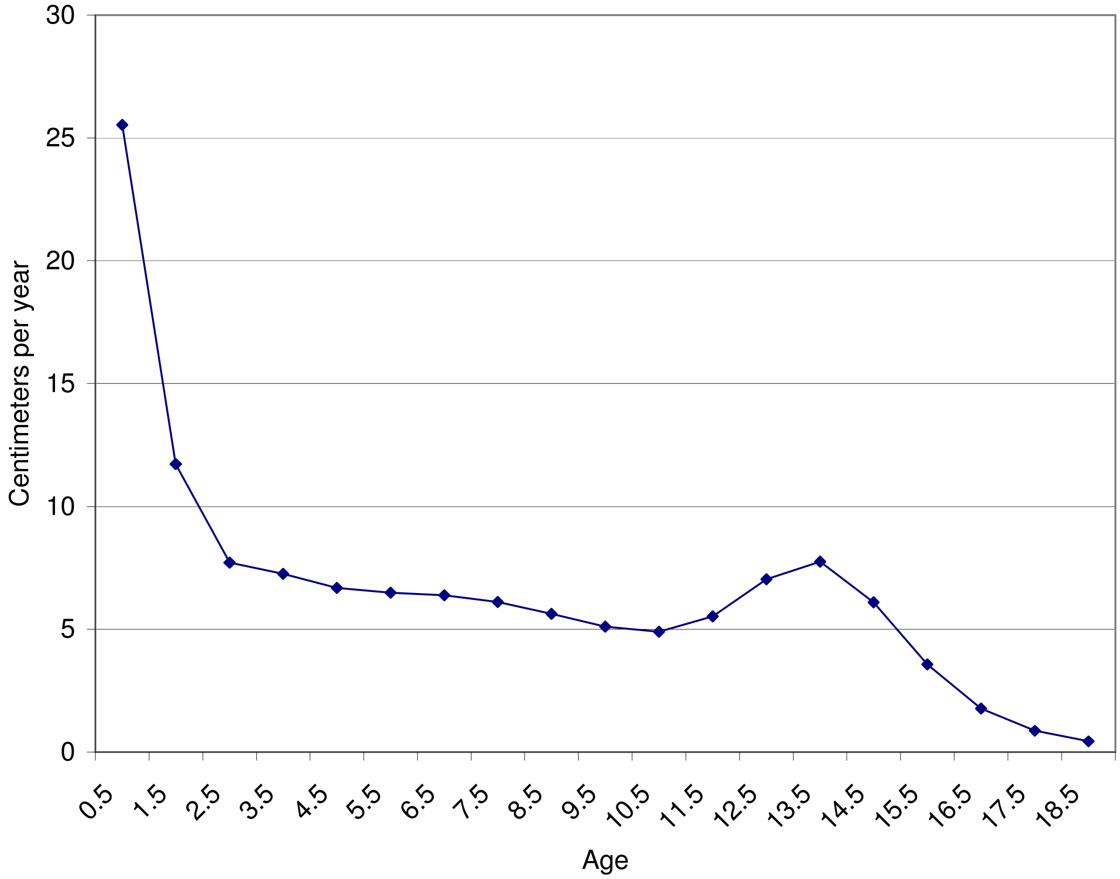
N = 39.

Table 5: Weighted Least Squares Regressions of Velocity Index on Relative Prices, the Palmer Index and the Crude Death Rate

Equation	Constant	cotton / pork (-1)	slave / pork (-3)	Palmer Index (-1)	cdr (-1)	R^2
1	133.94 (12.47)	-2867.93 (-2.65)				0.160
2	35.599 (1.81)		0.9620 (3.62)			0.262
3	102.32 (41.89)			-22.39 (-4.50)		0.353
4	101.94 (8.94)				0.1103 (0.40)	0.004
5	67.129 (3.22)	-952.55 (-0.81)	0.6244 (2.31)	-13.77 (-2.02)		0.440
6	60.589 (3.17)		0.5802 (2.20)	-17.23 (-3.26)		0.430

Source: Calculated from raw data in Figures 3-5. t-values in parentheses. N = 39.

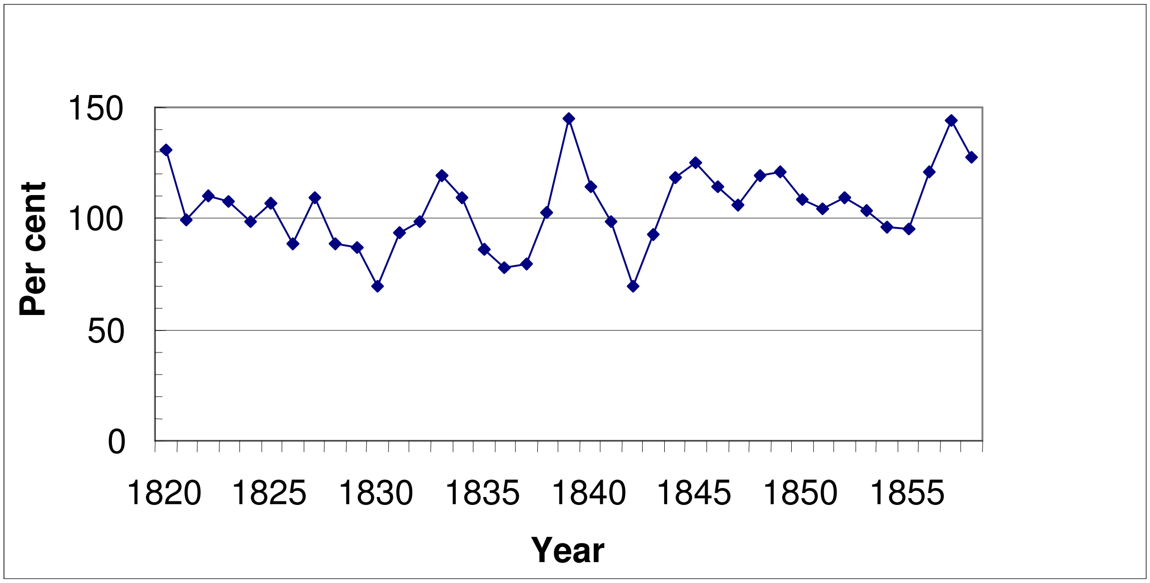
Figure 1: Boys' Growth under Good Conditions



Source: Calculated from data in Centers for Disease Control and Prevention, "CDC Growth Charts: United States."

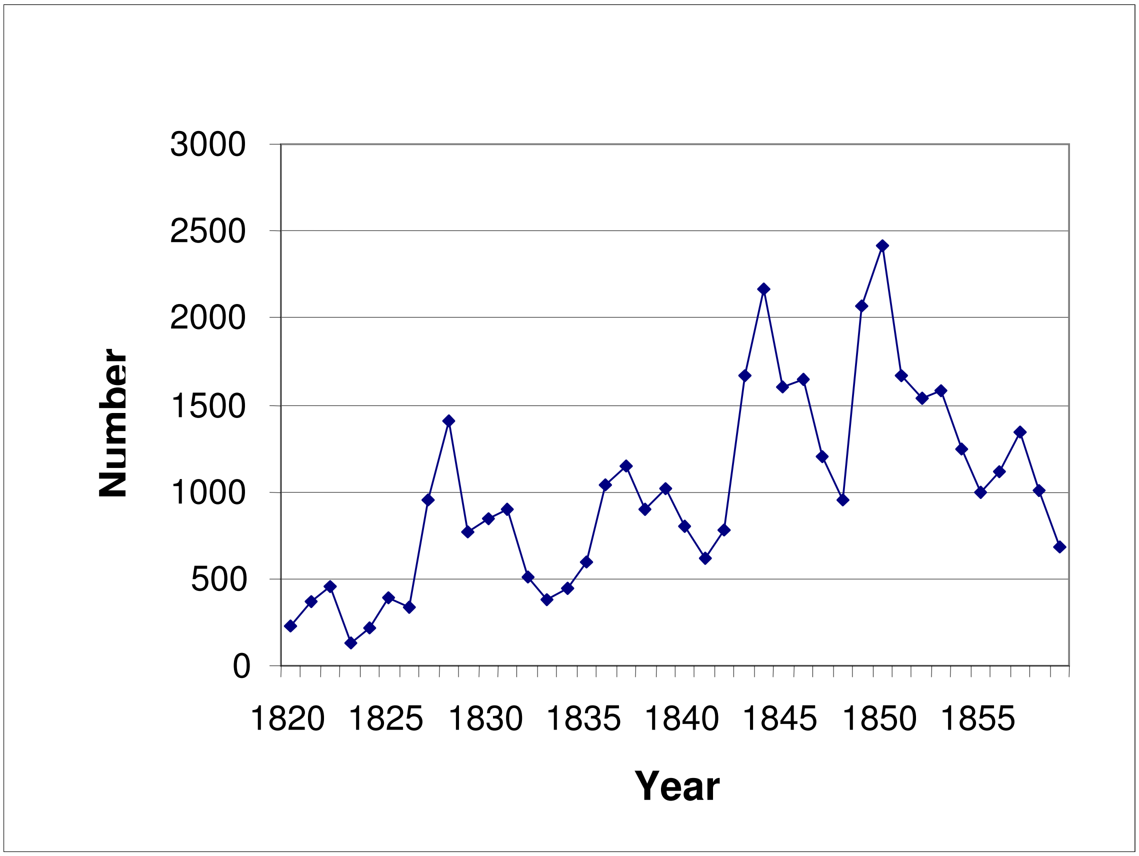
Figure 2: Genuine and Synthetic Longitudinal Measurements

Figure 3: Three Year Moving Average of Velocity at Ages 3-16 as a Per cent of Average



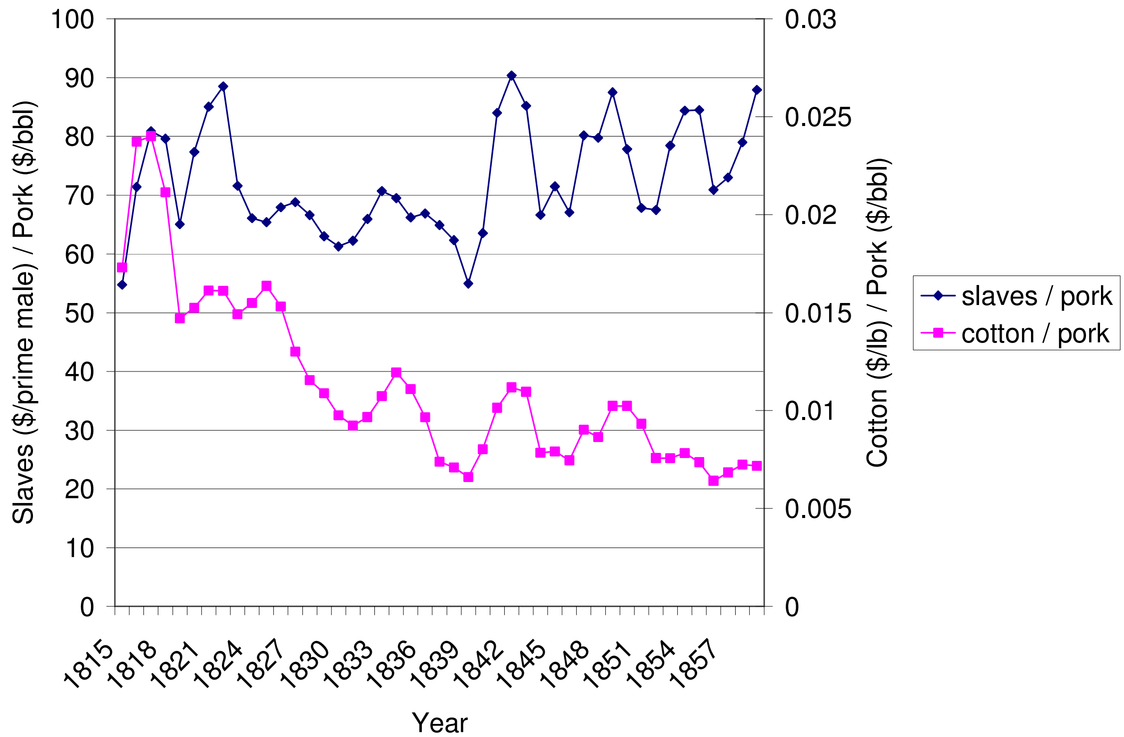
Source: Slave manifests for cotton states.

Figure 4: Sample Sizes Used to Calculate Annual Values of the Growth Velocity Index



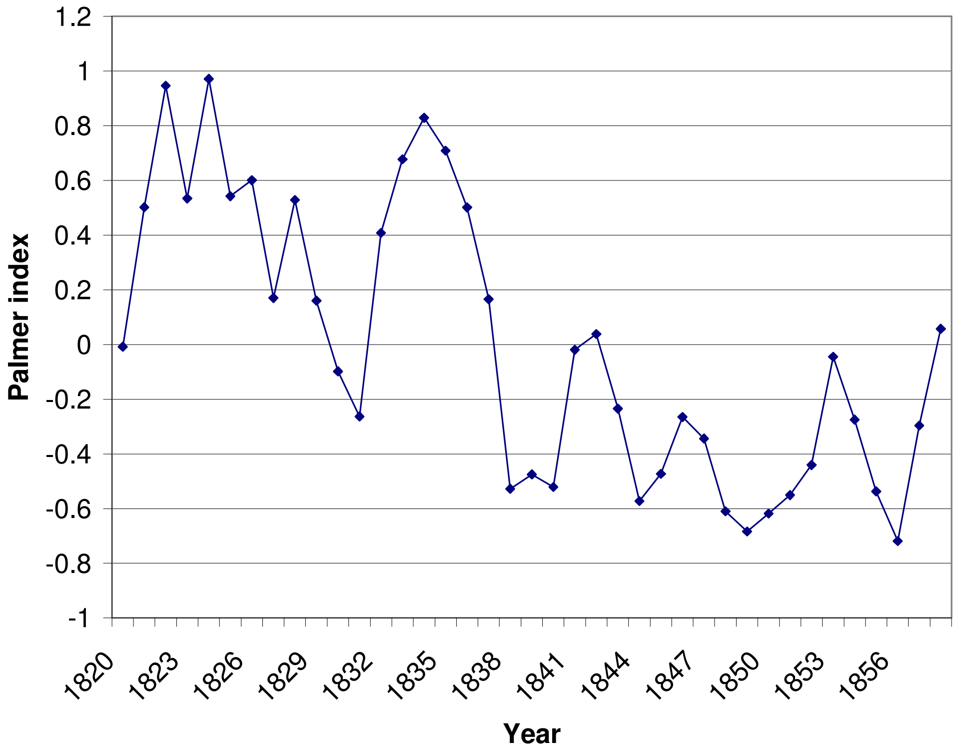
Source: Slave manifests for cotton states.

Figure 5: 3 Year Moving Average of the Ratios of Cotton and Slave Prices to the Price of Pork



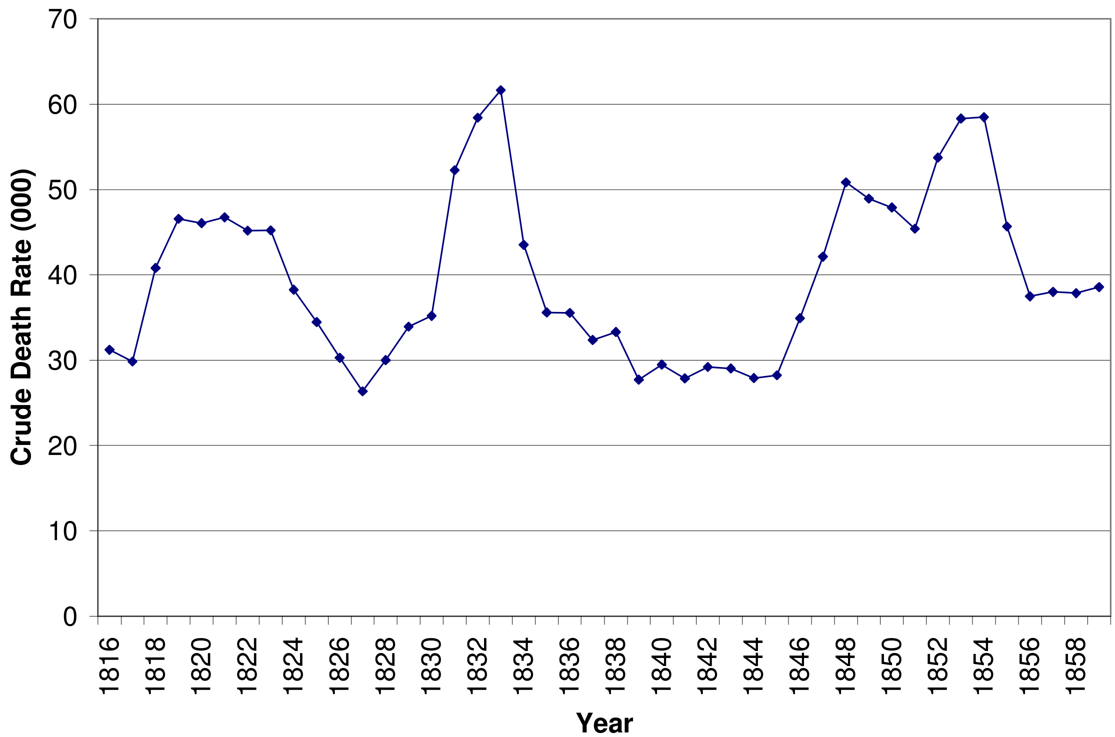
Sources: See note 20.

Figure 6: 3 Year Moving Average of the Palmer Drought Severity Index



Source: Calculated from National Geophysical Data Center, "Reconstructed PDSI Data Files."

Figure 7: 3 Year Moving Average of the Average of Crude Death Rates in Baltimore and New Orleans



Source: Haines, "The Urban Mortality Transition in the United States, 1800-1940.".
Raw data provided by the author.

References

Centers for Disease Control and Prevention. "CDC Growth Charts: United States." http://www.cdc.gov/growthcharts/: National Center for Health Statistics, 2000.

Coclanis, Peter A. *The Shadow of a Dream: Economic Life and Death in the South Carolina Low Country, 1670-1920*. New York: Oxford University Press, 1991.

Coelho, Philip R. P., and Robert A. McGuire. "Diets Versus Diseases: The Anthropometrics of Slave Children." *Journal of Economic History* 60, no. 1 (2000): 232-246.

Cole, Arthur Harrison, and International Scientific Committee on Price History. *Wholesale Commodity Prices in the United States, 1700-1861*. Cambridge, Mass.: Harvard University Press, 1938.

Floud, Roderick, Annabel Gregory, and Kenneth W. Wachter. *Height, Health and History: Nutritional Status in the United Kingdom, 1750-1980*, *Cambridge Studies in Population, Economy, and Society in Past Time; 9.* Cambridge: Cambridge University Press, 1990.

Fogel, Robert William, and Stanley L. Engerman. *Time on the Cross*. Boston: Little, 1974.

Genovese, Eugene D. *The Political Economy of Slavery; Studies in the Economy & Society of the Slave South*. New York: Vintage Books, 1967.

Gray, Lewis Cecil, and Esther Katherine Thompson. *History of Agriculture in the Southern United States to 1860*, *Carnegie Institution of Washington Publication; No. 430.* Washington: The Carnegie Institution of Washington, 1933.

Haines, Michael R. "The Urban Mortality Transition in the United States, 1800-1940." Cambridge, MA: National Bureau of Economic Research Working Paper No. H134, 2001.

Komlos, John. *The Biological Standard of Living in Europe and America, 1700-1900: Studies in Anthropometric History*. Aldershot, Great Britain: Brookfield Variorum, 1995.

———. *Nutrition and Economic Development in the Eighteenth-Century Habsburg Monarchy: An Anthropometric History*. Princeton, N.J.: Princeton University Press, 1989.

Kotlikoff, Lawrence J. "New Orleans Prime Male Prices." Los Angeles: UCLA, 1979.

National Geophysical Data Center. "Reconstructed PDSI Data Files." National Oceanic and Atmospheric Administration, 2004.

Phillips, Ulrich Bonnell. *American Negro Slavery: A Survey of the Supply, Employment and Control of Negro Labor as Determined by the Plantation Regime*. New York: D. Appleton, 1927.

Rees, R., et al. "Optimal Food Allocation in a Slave Economy." *Journal of Population Economics* 16, no. 1 (2003): 21-36.

Smille, Wilson G. "The Period of Great Epidemics in the United States." In *The History of American Epidemiology*, edited by Franklin H. Top, 52-73. London: Henry Kimpton, 1952.

Steckel, Richard H. "Birth Weights and Infant Mortality among American Slaves." *Explorations in Economic History* 23, no. 2 (1986): 173-198.

———. "Diets Versus Diseases in the Antrhropometrics of Slave Children: A Reply." *Journal of Economic History* 60, no. 1 (2000): 247-259.

———. "Growth Depression and Recovery: The Remarkable Case of American Slaves." *Annals of Human Biology* 12, no. 2 (1986): 111-132.

———. "The Health of American Slaves: New Evidence and Analysis." Columbus: Ohio State University, 1995.

———. "Height and Per Capita Income." *Historical Methods* 16, no. 1 (1983): 1-7.

———. "A Peculiar Population: The Nutrition, Health, and Mortality of American Slaves from Childhood to Maturity." *Journal of Economic History* 46, no. 3 (1986): 721-741.

———. "Percentiles of Modern Height Standards for Use in Historical Research." *Historical Methods* 29, no. 4 (1996): 157-166.

———. "Slave Height Profiles from Coastwise Manifests." *Explorations in Economic History* 16, no. 4 (1979): 363-380.

———. "Stature and the Standard of Living." *Journal of Economic Literature. December* 33, no. 4 (1995): 1903-1940.

Tanner, J. M. *Foetus into Man: Physical Growth from Conception to Maturity*. Cambridge, Mass.: Harvard University Press, 1978.

United States Bureau of the Census. *Historical Statistics of the United States, Colonial Times to 1970*. Dept. ed. [Washington]: U.S. Dept. of Commerce, Bureau of the Census: for sale by the Supt. of Docs., U.S. Govt. Print. Off., 1976.

Wesley, Charles H. "Manifests of Slave Shipments Along the Waterways, 1808-1864." *Journal of Negro History* 27, no. 2 (1942): 155-174.

Footnotes

[1] See, for example, Roderick Floud, Annabel Gregory, and Kenneth W. Wachter, *Height, Health and History: Nutritional Status in the United Kingdom, 1750-1980*, *Cambridge Studies in Population, Economy, and Society in Past Time; 9.* (Cambridge: Cambridge University Press, 1990), John Komlos, *The Biological Standard of Living in Europe and America, 1700-1900: Studies in Anthropometric History* (Aldershot, Great Britain: Brookfield Variorum, 1995), John Komlos, *Nutrition and Economic Development in the Eighteenth-Century Habsburg Monarchy: An Anthropometric History* (Princeton, N.J.: Princeton University Press, 1989), Richard H. Steckel, "Height and Per Capita Income," *Historical Methods* 16, no. 1 (1983), Richard H. Steckel, "Stature and the Standard of Living," *Journal of Economic Literature. December* 33, no. 4 (1995).

[2] Eugene D. Genovese, *The Political Economy of Slavery; Studies in the Economy & Society of the Slave South* (New York: Vintage Books, 1967).

[3] Robert William Fogel and Stanley L. Engerman, *Time on the Cross* (Boston: Little, 1974).

[4] Charles H. Wesley, "Manifests of Slave Shipments Along the Waterways, 1808-1864," *Journal of Negro History* 27, no. 2 (1942).

[5] Richard H. Steckel, "A Peculiar Population: The Nutrition, Health, and Mortality of American Slaves from Childhood to Maturity," *Journal of Economic History* 46, no. 3 (1986), Richard H. Steckel, "Slave Height Profiles from Coastwise Manifests," *Explorations in Economic History* 16, no. 4 (1979).

[6] Many slaves exported from North Carolina may have departed through ports in South Carolina, and so the small number of North Carolina exports might not indicate a deficiency in the records.

[7] Fogel and Engerman, *Time on the Cross*.

[8] Richard H. Steckel, "Birth Weights and Infant Mortality among American Slaves," *Explorations in Economic History* 23, no. 2 (1986).

[9] For comparisons see Richard H. Steckel, "Growth Depression and Recovery: The Remarkable Case of American Slaves," *Annals of Human Biology* 12, no. 2 (1986)..

[10] Steckel, "A Peculiar Population: The Nutrition, Health, and Mortality of American Slaves from Childhood to Maturity."

[11] See the exchange in Philip R. P. Coelho and Robert A. McGuire, "Diets Versus Diseases: The Anthropometrics of Slave Children," *Journal of Economic History* 60, no. 1 (2000), Richard H. Steckel, "Diets Versus Diseases in the Antrhropometrics of Slave Children: A Reply," *Journal of Economic History* 60, no. 1 (2000).

[12] Steckel, "A Peculiar Population: The Nutrition, Health, and Mortality of American Slaves from Childhood to Maturity."

[13] Fogel and Engerman, *Time on the Cross*.

[14] J. M. Tanner, *Foetus into Man: Physical Growth from Conception to Maturity* (Cambridge, Mass.: Harvard University Press, 1978).

[15] Arguably the weights should be inversely proportional to the standard errors of the estimated velocities, which depend on the variances of the heights at adjacent ages and the sample sizes used to estimate the means. Because the variances of the heights are roughly equal, by far the largest variation in the standard errors arises from the varying sample sizes across ages. On this basis I calculated the weights as follows:

$$w_{i,j,k} = \frac{1.0 \Big/ sqrt\left[\frac{(n_{i+1,j+1,k} + n_{i,j,k})}{(n_{i+1,j+1,k} + n_{i,j,k} - 2)}\left(\frac{1}{n_{i+1,j+1,k}} + \frac{1}{n_{i,j,k}}\right)\right]}{\sum_{i=3}^{i=16} 1.0 \Big/ sqrt\left[\frac{(n_{i+1,j+1,k} + n_{i,j,k})}{(n_{i+1,j+1,k} + n_{i,j,k} - 2)}\left(\frac{1}{n_{i+1,j+1,k}} + \frac{1}{n_{i,j,k}}\right)\right]}$$

where n refers to sample size and the index counters i, j, and k refer to age, year and sex, respectively. The first term within the square root increases the penalty (decreases the weight) for very small samples.

[16] The slow growth of both rice exports and the black population suggest that region may have shed some slaves in the late antebellum period. See Peter A. Coclanis, *The Shadow of a Dream: Economic Life and Death in the South Carolina Low Country, 1670-1920* (New York: Oxford University Press, 1991).

[17] For a discussion of the growth of the antebellum sugar industry see Lewis Cecil Gray and Esther Katherine Thompson, *History of Agriculture in the Southern United States to 1860*, *Carnegie Institution of Washington Publication; No. 430.* (Washington: The Carnegie Institution of Washington, 1933).

[18] R. Rees et al., "Optimal Food Allocation in a Slave Economy," *Journal of Population Economics* 16, no. 1 (2003).

[19] Richard H. Steckel, "The Health of American Slaves: New Evidence and Analysis," (Columbus: Ohio State University, 1995), Steckel, "Slave Height Profiles from Coastwise Manifests."

[20] The sources for the price data are: (1) slaves: Lawrence J. Kotlikoff, "New Orleans Prime Male Prices," (Los Angeles: UCLA, 1979), United States Bureau of the Census., *Historical Statistics of the United States, Colonial Times to 1970*, Dept. ed. ([Washington]: U.S. Dept. of Commerce, Bureau of the Census: for sale by the Supt. of Docs., U.S. Govt. Print. Off., 1976)., series E-118 and E-126; (3) Virginia corn: Gray and Thompson, *History of Agriculture in the Southern United States to 1860.*, Table 50; and (4) Cincinnati mess pork (average of monthly quotes): Arthur Harrison Cole and International Scientific Committee on Price History., *Wholesale Commodity Prices in the United States, 1700-1861* (Cambridge, Mass.: Harvard University Press, 1938).

[21] National Geophysical Data Center, "Reconstructed PDSI Data Files," (National Oceanic and Atmospheric Administration, 2004).

[22] Wilson G. Smille, "The Period of Great Epidemics in the United States," in *The History of American Epidemiology*, ed. Franklin H. Top (London: Henry Kimpton, 1952).

[23] Michael R. Haines, "The Urban Mortality Transition in the United States, 1800-1940," (Cambridge, MA: National Bureau of Economic Research Working Paper No. H134, 2001).

[24] See the discussion of geographic differences in Steckel, "Stature and the Standard of Living."

[25] Parameter estimates for equations similar to those in Table 5 are statistically insignificant.

[26] Other approaches may be fruitful, such as models that explain heights of children as a function of the annual values of the independent variables from birth to the age of measurement.

[27] Ulrich Bonnell Phillips, *American Negro Slavery: A Survey of the Supply, Employment and Control of Negro Labor as Determined by the Plantation Regime* (New York: D. Appleton, 1927).