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Areendam Chanda
Department of Economics
Louisiana State University
email: achanda@lsu.edu

Lee A. Craig
Department of Economics
North Carolina State University
email: lee_craig@ncsu.edu

Julianne Treme
Department of Economics
Wake Forest University
email: tremej@wfu.edu

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Department of Economics
Louisiana State University
Baton Rouge, LA 70803-6306
http://www.bus.lsu.edu/economics/

CONVERGENCE (AND DIVERGENCE) IN THE BIOLOGICAL STANDARD OF LIVING IN THE UNITED STATES, 1820-1900

Areendam Chanda [a], Lee A. Craig [b], Julianne Treme [c]

[a] *Department of Economics, Louisiana State University, Baton Rouge, LA 70803, United States*

[b] *Department of Economics, North Carolina State University, Raleigh, NC 27695-8110, United States*

[c] *Department of Economics, Wake Forest University, Winston-Salem, NC 27106 United States*

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Abstract

Standard economic indicators suggest that the United States experienced long-run economic growth throughout the nineteenth century. However, biological indicators, including human stature, offer a different picture, rising early in the century, falling (on average) mid-century, and rising again at the end of the century. This pattern varied across geographical regions. Using a unique data set, consisting of mean adult stature by state, we test for convergence in stature among states in the nineteenth century. We find that during the period of declining mean stature, heights actually diverged. Later in the century we find a type of "negative" convergence indicating that stature among states tended to converge to a new, lower steady state. Only towards the end of the century do we find classic convergence behavior. We argue that the diversity of economic experiences across regions, e.g. urbanization, industrialization, and transportation improvements, explain this pattern of divergence and then convergence.

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E-mail addresses: achanda@lsu.edu (A.Chanda), lee_craig@ncsu.edu (L.A. Craig), tremej@wfu.edu (J. Treme)

1. Introduction

Among economists the comparison of living standards across geographical regions dates at least from Adam Smith. Examining the economic performance of Britain relative to her North American colonies, Smith observed "the rapid progress of our American Colonies towards wealth and greatness" (Smith 1776 [1937], pp. 346-347). In his notion of national wealth Smith was grasping for what would become standard economic measures of output, including per capita gross domestic product. Later, Karl Marx addressed the connection between those standard economic indicators and biological ones through the negative externalities that accompanied industrialization, and he explicitly recognized the role of human stature in his assessment of the declining welfare of the population (Floud 1994).

With the advent of national income accounting in the twentieth century economists took a more comprehensive look at the comparative economic performance of nation states. Alexander Gerschenkron's (1952) seminal work on "economic backwardness" was followed by Robert Solow's (1956) formal modeling of economic growth, and Simon Kuznets' (1966) extended the idea by focusing on international comparisons of "modern economic growth".[1] Implicit in this body of literature rested the notion that the *rate* of output growth was a function of the *level* of output. Economic forces led (some) poorer countries to grow faster than (some) richer ones; hence there existed a set of countries among which was the tendency for living standards to converge. Subsequently, Baumol (1986) and Barro (1991) and Barro and Sala-i-Martin (1991, 1992) presented formal models of per capita income convergence across countries and regions, including the United States. More recently, the topic has been extensively explored and developed in both empirical and theoretical literatures. With respect to the United States, like Barro and Sala-i-Martin, Mitchener and McLean (1999) demonstrate economic convergence between geographical regions.

All of these studies focus on standard economic indicators, such as earnings, gross domestic product, and per capita income; however, following Komlos's (2006) exploration of convergence of stature across regions of the Habsburg Empire in the nineteenth and early twentieth centuries, we investigate the convergence of biological indicators of the living standard in the United States. Specifically we ask: Did human stature in the 19th-century United States converge, across states, to a long-run national norm?

Human stature is among the ultimate biological manifestations of the consumption of net nutrients, and as such, stature serves as a primary indicator of the biological standard of living (Steckel 1995). Stature measurements in early American history can be used to assess how historical events, including the geographical expansion of agricultural output, industrialization and urbanization, and the improvement of the transportation network, impacted the standard of living and health status of Americans. While a person's genes may determine adult height potential, whether that potential is realized or not depends on the economic and disease environment in which the individual matures (Tanner 1978; Thoday 1965). Thus, the comparison of mean adult heights, over time, by state reflects environmental changes, including nutrition, work intensity, and exposure to disease.

Net nutritional status is the difference between caloric inputs and caloric demands of work, body maintenance, and disease. A positive net nutritional status stimulates growth while a negative net nutritional status will retard growth, *ceteris paribus*.[2] Thus, as Cuff (2005) explains, adult stature can be viewed as a "cumulative indicator of net nutritional status over the growth years" (p. 10). Changes in nutrition, work conditions, and disease environment can all influence net nutritional status. Therefore the change in adult mean stature within a country over time documents, to a substantial extent, change in the economic and social climate. Since food consumption in the early phase of the Industrial Revolution accounted for three fourths of total income of the laboring class, economic well-being can be directly linked to nutritional status and hence stature (Komlos 1994). Stature is a unique variable in this regard in that it offers a measure of the "actual physical outcomes of economic activity" (Cuff 2005, p. 11), and thus changes in the environment are the driving force behind changes in average height since genetic differences – i.e. divergence from the mean - approximately cancel in averages across populations.

The consumption of nutrients, net of those exhausted during work or while fighting disease, determines whether *homo sapien* populations achieve their genetic height potential. Higher-income individuals have the ability to purchase higher-quality goods, protein-rich food, housing, and medical care and the goods can be seen as being positively correlated with health and therefore human stature (Auster et al. 1969; Sunder 2003). Conversely, a low level of income may limit the quality and quantity of food intake, and historically was associated with jobs requiring hard labor, long hours, and working conditions that were unpleasant and dangerous for long periods of time. This placed increased demands on nutrition entering the body for maintenance, leaving little left over for growth. The affordable foods were more likely to be high in carbohydrates (e.g. grains, which were less perishable than meat and dairy products) and less likely to provide the additional nutrients needed for catch-up growth when a nutritional deficiency occurred in a critical period of development - particularly infancy and early adolescence (Komlos and Coclanis 1997). This should not be taken as evidence that low-income individuals went hungry. As Komlos (1998) suggests, “Utility is maximized subject to a weight (or volume) constraint not a nutrient constraint, inasmuch as consumers did not know about nutrient contents of food such as vitamins, minerals, and proteins” (p. 785).

Cultural and technological impacts cannot be ignored either (Mokyr 2000). Personal and household hygiene; as well as technologies, such as running water, sewers, washing machines; the impact of work intensity, and refrigeration, and the relative price of key foods, such as fresh meat and dairy products all played a role in net nutrition (Baten and Murray 2000, Goodwin et al. 2002, Craig et al. 2004). The emergence of factories increased urbanization and concentrated the workforce, leading to increased exposure to infectious disease in the absence of effective public health measures.

Paradoxically, in the mid-nineteenth century United States, stature declined, but economic growth, as measured by the growth of income per capita, increased (see below). This phenomenon, the so-called “Antebellum Puzzle” (Komlos 1996; Haines et al. 2003), or the divergence between economic and biological indicators, highlights the importance of studying stature and suggests one cannot focus solely on income to characterize the overall economic climate of the times.[3] This is especially true when the environment is marked by complex interactions of life and work patterns resulting from social change, such as industrialization, which in the nineteenth century produced negative health and mortality consequences. If the decline in net nutritional status overshadows the advantages conferred by higher incomes, then the mere fact incomes have risen cannot be interpreted as a sign that on average people were unambiguously better off.[4]

In attempting to identify the cause of the Antebellum Puzzle, economic historians have identified a number of suspects. The absence of the germ theory of disease would have limited the benefits high-income populations derived from increased access to healthcare.

Urbanization also could account for the decline in height, as populations lived closer together and were exposed to a wider disease nexus in the absence of effective public health measures.[5] The increase in population forced farmers to search for new land, which was often less suitable for farming, decreasing marginal products, *ceteris paribus* of course, and increasing the risk of debilitation from disease, most notably malaria. The rising price of food, especially animal products, would have caused some people to substitute carbohydrate rich foods (sugar, grains) for protein rich foods (meat and dairy products), thereby robbing the growth process of a fundamental input (Komlos 1987; Komlos and Coclanis 1997). While transportation improvements allowed larger segments of the population to enjoy a more varied diet, they came with a cost, as food was less dense in nutrients upon arrival.[6]

In addition, transportation improvements had conflicting impacts on the biological standard of living. On the one hand, transportation improvements increased migration and trade and thus expanded the disease nexus, which, *ceteris paribus*, would have had a negative impact on the biological standard of living. Haines (et al. 2002) find a negative impact on adult stature from growing up in a U.S. county with access to rail or water transportation, and self-sufficient regions – that is, those marked by an absence of trade – did not experience the Antebellum Puzzle to the same extent as those located on trade rates (Sunder 2004). On the other hand, by facilitating trade, transportation improvements increased real output and put upward pressure on living standards (conventionally measured); thus, through the income effect, improvements had the potential to increase the biological standard of living as well. For example, the heights of U.S. slaves did not decline during the antebellum era (Rees et al. 2003), suggesting slave owners maintained net nutrients, and higher-income Americans did not experience across-the-board height declines during the antebellum period, even in a trading center like New York (Sunder 2003). In the end, the relative weights of these factors remain an empirical question.

Figure 1 illustrates average adult height for native-born white males, by birth cohort, for each decade between 1800 and 1900. The graph shows there is not a unidirectional, upward trend in stature in the nineteenth century. Human stature rose early in the century, fell mid-century, and began to rise again at the end of the century. Americans born before 1830 were taller than Americans born in subsequent decades. Specifically, those born in 1830 were more than an inch taller than those born in 1890. Although mean height bottomed out with the birth cohort of 1890, and began rising thereafter, mean height did not reach 1830 levels again until 1920.

The stature literature examines the relationship between income and height - using height as an indicator of health - and the socioeconomic and geographical determinants of height; however, only recently have scholars extended the convergence idea to stature (Bassino 2006; Komlos 2006). Convergence examines the effect of initial conditions on long-run economic outcomes. If the effect of the initial condition eventually dies out, with initially shorter populations having higher growth rates than that experienced by taller populations, then one cannot reject the so-called “absolute convergence” hypothesis under which the shorter populations converge on the taller ones from below. If one fails to find evidence of absolute convergence, it is possible to test for the existence of so-called “conditional” convergence, which reflects the possibility that while initial conditions die out, each region moves to its own (long-run) steady state rather than a universal steady state. If conditional convergence were present, poor (short) regions would grow faster than rich (tall) ones but only after controlling for other variables that influence the steady state differences. Thus in what follows we test for these various forms of convergence, and we answer the question of whether and how heights converged (or diverged) across the various regions in the United States during the nineteenth century.

2. Model

The basic framework for testing for convergence was laid out by Barro (1991) and Barro and Sala-i-Martin (1991, 1992), and addresses the question of whether poor states, regions, or countries tend to grow faster than rich ones. The papers analyze the forces leading to convergence over time in the levels of per capita income and product. Generally speaking, the authors find evidence of convergence: poorer regions and countries do grow faster than rich ones on average. Employing a neoclassical growth model for closed economies, as presented by Ramsey (1928), Solow (1956), Koopmans (1965) and Cass (1965), Barro derives, from the following nonlinear univariate equation, what has come to be known as the “Barro regression,” which assumes that the rate of convergence is exponential and constant throughout the period in question.

$$\frac{1}{T}\log[\frac{y_{i,T}}{y_{i0}}] = a - [\frac{1-e^{-\lambda T}}{T}] * \log(y_{i0}) + w_{i0,t}\,, \tag{1}$$

Where y_i is income of the *ith* country or region; T is time; λ is the speed of convergence, and w is a disturbance term. If $\lambda > 0$, then Equation (1) implies that poor economies tend to grow faster than rich ones.

Transforming (1) yields the following more general version of Barro's equation, which can be used to test the absolute convergence hypothesis as it relates to height:

$$\hat{h}_{i,t,,t+T} = a + \beta \log h_{i,t} + e_i\,, \tag{2}$$

where the dependent variable, $\hat{h}_{i,t,,t+T}$, is the growth rate of height in country or region *i* between t and t+T and is measured as $\frac{\log h_{i,t+T} - \log h_{i,t}}{T}$ and the independent variable, $\log h_{i,t}$, is the natural log of height at time t. If the sign on β is negative, and if one can reject the hypothesis that β=0, then it can be said that the data exhibit absolute beta convergence. In short, one is rejecting the null hypothesis of no convergence, and by extension one can conclude that the stature of the population of each region is converging to the same long-run, steady state.

The Barro equation used for conditional convergence is

$$\hat{h}_{i,t,,t+T} = a + \beta \log h_{i,t} + \psi V_i + e_i\,. \tag{3}$$

Where *V* is a vector of additional explanatory variables; thus this regression holds the additional explanatory variable constant to obtain an estimate of β. Conditional convergence abandons the assumption that all states have homogeneous economic and social environments and the same steady state, and it implies states will grow faster the further they are from *their* unique steady-state value. The additional explanatory variables influence the transitional growth rate and are determinants of the steady-state position. After controlling for factors impacting steady state positions, conditional convergence implies a negative correlation between growth and initial level of height. In other words, holding the new explanatory variables constant, states with low average heights must grow at a faster rate than states with high average heights in order to achieve conditional convergence. Thus the sign of β is still the key indicator of convergence.

3. Results

To investigate the questions outlined above, we employ a unique data set, which contains estimates of mean adult height, by birth cohort and by state, for native-born white males in ten-year intervals from 1800 to 1900. (Details of the data are discussed in the appendix.) In order to check the accuracy of our state-level estimates, we construct national estimates (weighting the state-level estimates by population), which we then compared to other national estimates. Table 1 illustrates the results of this comparison. With the exception of 1900, the estimates are very close to other benchmark figures reported in Steckel (1995) and Costa and Steckel (1997). Indeed, in eight of the eleven years, the differences in the means were smaller than eight-hundredths of an inch. Thus we are confident the technique produces estimates that do not deviate too greatly from the true data.

Table 2 contains the least squares estimates, in the form of a Barro regression, for 26 U.S. states for various, overlapping time periods in the nineteenth century. Since decadal data are only available for 26 states from 1820-1900, the sample is limited to restrict attention to the changes in average height over the same set of states. The econometric specification is based on equation (2) above. Under the assumption that the processes driving long-run economic growth are in fact "long run," the dependent variable is the growth rate in height over a twenty-year period beginning in year t, and the independent variable is the log of initial average height in year t.[7] For example, in column 1 the variable "Log of initial Height in 1820" is the log of average height for white males born in 1820, and the "Growth Rate" is the growth rate between 1820 and 1840. Each cell contains the resulting estimate of β, the standard error for this estimate (in parentheses), and the R^2. (All equations have been estimated with constant terms that are not reported in the table.)

3.1. Absolute Divergence

Absolute divergence is evident in the first four regressions – that is through 1870. The coefficient on log of initial height is positive and significant indicating that on average, there is an increasing gap in the difference between average heights across states. The relationship between the growth rate and initial average height is shown in Figures 2 through 5. Figures 2 through 4, covering the period 1820-1860, show the growth rate of estimated mean adult stature was negative, and thus average height was declining across the United

States. This is the "Antebellum Puzzle." While no state experienced an increase in height over the initial three time periods, there is evidence of absolute divergence, or a widening gap between the tall and short states. As an example, compare the position of Rhode Island and Arkansas as they appear in Figures 2 through 4. The Rhode Island population is consistently one of the country's shortest, and it experiences larger declines in stature than nearly every other state in the sample. Arkansas is consistently one of the tallest states and the decline in stature is smaller than nearly all other states in the sample. The gap widens because subsequent birth cohorts in an initially short state, Rhode Island, are getting shorter faster than those of an initially tall state, Arkansas.

Contrast antebellum height behavior with income measures over the same time period. Table 3 shows antebellum income estimates. From 1800-1860, real GDP capita grew at 0.92 percent per annum, and growth was faster during the second half of the period, as the growth rate was 1.33 percent per annum after 1830. The income and height evidence at the national level in Table 3 and the average height measurements by state in Figures 2 through 4 illustrate the divergence of income and height trends that define the Antebellum Puzzle.

Figure 5, covering the 1850-1870 period, also displays absolute divergence, though the growth rate of mean height was positive for 15 of the 26 states, marking the beginning of the end of the Antebellum Puzzle. However, the state with increasing mean height tended to be states with initially taller populations. Thus the increasing height of subsequent birth cohorts in the tall states and simultaneous decline in the short states caused the height gap to widen. The tall were getting taller, or still in some cases shorter at a slower rate, while the short were getting shorter. For instance, Arkansans was getting taller while Rhode Islanders were still shrinking. This represents divergence, though a slightly different type of divergence than in the earlier decades in which the mean heights were falling across the board.

3.2. "Negative" Absolute Convergence

As the divergence dies out, a post-Civil-War puzzle emerges. Initially "tall" states begin to experience larger height declines than initially "short" states. The β coefficient for the regression 1870-1890 is negative and significant. The relationship can be appreciated from the scatter plot in Figure 6, in which the average growth rate of height between 1870 and 1890 is plotted against the log of height in 1870. The negative coefficient is statistically significant at the 1 percent level, suggesting absolute convergence across states, but it is convergence of a peculiar kind—peculiar at least by the standards of the Barro-type results and what one generally finds in the growth literature. Since the growth rates were negative, as evidenced by the graph, states with a higher average height in 1870 experienced larger declines in their growth rates than states with a lower average height. Heights are then converging by the population becoming shorter by1890. In other words, states are displaying a form of negative convergence in that the tall states converged on the short states from above; thus the new steady state was one of overall shorter stature. Thus the puzzle continues.

3.3. Conditional Convergence

The relation between growth rates and initial levels of height is not statistically significant in either the 1860-1880 period or the 1880-1900 periods (Table 2). The divergence and negative convergence associated with the antebellum puzzle appears to be at an end, but the absence of absolute convergence suggests testing for conditional convergence.

A possible explanatory variable affecting steady state height is geographic location. To the extent geography reflects key variables such as transportation and urbanization, which would have played a role in the decline in heights as populations were living closer together and the possibility of spreading disease was higher, it would be expected to contribute to regional differences in steady states. States in the South were more likely to be rural than Northeastern states. Therefore, on average, Southern males would be expected to be taller than males of the Northeast. Thus a regional dummy for the South has been added as an explanatory variable to capture effects common to states in this region.[8]

When the dummy variable for the South was added to the regression over the time period 1860-1880, Table 4 shows the estimated β coefficient on the natural log of height in 1860 was positive and insignificant; while the β coefficient on the Southern dummy variable was positive and significant. Figure 1 above shows that the United States experienced cycles in average height in the nineteenth century, with average heights rebounding briefly in 1870.

Given the rebound of height in 1870 and the subsequent decline and then rise again after 1880, the 1870s appears to be an anomalous decade. Perhaps the uneven regional recovery from the war - rapid in some places and slow in others - contributed to this record. To get a better sense of what happens during this period, we include convergence tests for ten-year periods beginning with 1860, and Table 4 shows the least squares estimates in the form of a Barro regression testing for both absolute and conditional convergence. As with table 2, each column contains an estimate of β, the standard error for this estimate (in parentheses), and the R^2. The conditional convergence regressions (in columns 1, 3, and 4) include additionally the southern regional dummy variable, the coefficients and standard errors for which are also reported in the table.[9]

Figure 7 shows the relationship between the growth rate and initial log of height for the decade 1860-70 and forms the basis of the estimates in column 2 of Table 4. Figures 8 and 9 show the relationship between the growth rate and initial log of height for the following two decades when the regional dummy variable is held constant. These plots are based on the estimates in columns 3 and 4 of Table 4. The log of average height of each state in 1860, 1870, and 1880 is shown on the horizontal axis in each of these three figures. The vertical axis displays the growth rate of average height from 1860-1870, 1870-1880, and 1880-1900 respectively. The growth rates in Figures 8 and 9 differ in construction from Figures 2 through 7 since the regional effect is controlled for. Note that once the regional effect is controlled for, the gap between tall and short states begins to shrink, because taller states experience faster, negative growth rates than shorter states.

Absolute divergence was found in the 1860-1870 period. Figure 7 is similar to Figure 5 and demonstrates the positive relationship between growth rates and initial height over the period 1860-1870. A tall state, like Arkansas, in 1860 would grow faster than a short state, like Rhode Island, and thus increase the height gap.

However, as shown in Figure 8, the result turned around after 1870. The similarity can be seen when compared with Figure 6. When the dummy variable for the South was added to the regression over the time period 1870-1880, the estimated β coefficient was negative and confirmed existence of conditional convergence – but again, negative conditional convergence. The states with short populations begin to see their height decrease more slowly than states with tall populations. Again, the tall are converging on the short from above.

Overall, the offsetting effects of negative conditional convergence in the 1870-1880 period and absolute divergence in the 1860-1870 period must be driving the absence of either convergence or divergence over the 1860-1880 period. That is, once the regional effects are controlled for, and the twenty-year period broken in two sub-periods, the decline in the growth rates of height in the 1870-1880 decade are balanced by the average height gains in the 1860-1870 decade.

Only at the end of the century does the pattern begin to look more like that found in the growth literature. While absolute convergence was not found in the 1880-1900 period (see Table 2, column 7), conditional convergence is evident for the 1880-1900 period (Table 4, column 4). The estimated regression including the southern region dummy yielded a significant and negative β coefficient, suggesting a negative, partial relationship between filtered growth rates and initial income. Figure 9 displays this relationship. Thus, after the regional effects are accounted for, growth rates were mainly positive, implying a form of positive convergence. This is a Barro-type result in that states with relatively short populations experienced more rapid growth in stature than in states with initially taller populations, thus closing the height gap. Not coincidentally, this period when traditional convergence in heights begins also marks the end of the Antebellum Puzzle (and the Postbellum Puzzle, as well). Mean adult stature begins to display classic convergence behavior and follows the standard economic indicators after 1880, and stature begins its long-run increase, which continued into the twentieth century.

Of course, we are interested in more than simply the sign and statistical significance of β. Barro and Sala-i-Martin (1992) and Mankiw et al. (1992) estimate the speed of convergence to be in the range of approximately 2-3 percent per annum. If similar calculations are done for height using the time period 1870-1890, one obtains a value of beta of -0.012, which implies a half-life of approximately 53 years and a convergence rate of 1.3 percent annually. The finding is very similar to the Mankiw et al. (1992) estimates from their conditional-convergence regressions, Komlos's estimates (2006) for the Habsburg Monarchy, and Bassino's estimates for Japan.

4. Discussion

The pattern of convergence demonstrated in Figures 2 through 9 illustrates the evolution of the U.S. economy as it experienced divergence, negative convergence and ultimately positive convergence in the biological standard of living during the course of the nineteenth century. The widening height gap between the tall and short populations in the early part of the century can be attributed to some combination of urban and rural differences, transportation improvements, and industrialization; while the negative convergence found after the Civil War can be explained by increasing commercialization efforts, particularly in the South (Komlos and Coclanis 1997). An unexpected Midwest height decline in the period 1870-1890 can be accounted for by industrialization, urbanization, and possibly by increasing income inequality. The positive convergence at the end of the century indicates the economy was moving towards a stage of development in which the negative externalities of industrialization and urbanization had been ameliorated by a number of social and economic factors including mastery of the germ theory of disease.

4.1. Antebellum Period and Divergence

The divergence evident in Figures 2 through 4 is consistent with previous research of the nature of economic growth during the antebellum period. The divergence can be attributed in part to differences in the experiences of urban and rural populations. Urbanization would have contributed to the decline in heights as urban population densities were much higher than those of rural areas, and thus the possibility of spreading disease was higher, especially in the absence of effective health measures (public or private). Fogel (1986) finds urbanization explains approximately 20 percent of the stature decline for birth cohorts from 1830 to 1860. Steckel (1995) notes a rural height advantage throughout the nineteenth century with its peak occurring in the early part of the century. Haines et al. (2003) provides further evidence of a negative relationship between height and urbanization during the antebellum period.

The urban-rural height differential can be decomposed further by considering geographic location. States in the South were more likely to be rural; whereas Northeastern states were more likely to be urban. Therefore, on average, Southern males would be expected to be taller than males of the Northeast, *ceteris paribus*, of course. The present study supports this hypothesis, as Northeastern populations were shorter than their Southern counterparts in every decade. Referring back to Figures 2 through 4, a tall, Southern state, such as Arkansas, incurred smaller declines in stature than a short, Northeastern state, such as Rhode Island.

Evidence from the British experience suggests the divergence may also be attributed to diet differences between urban and rural areas (Clark et al. 1995), a view that is not inconsistent with that of Komlos and Coclanis (1997). As incomes rose, urban residents were able to purchase a greater variety of food products. The choices made by parents impacted their children's growth and subsequently their stature. Urban diets were high in caloric quantity - including sugar and alcohol - but less likely to be the type of nutrients necessary to fuel growth. This was a consequence of the nutrient source shifting away from fresh meat and dairy produced and consumed on the farm and towards processed (and less fresh) foods and beverages in urban areas. The lack of quality nutrients and protein would have diminished net nutritional status and slowed or even stunted growth in urban areas.

Transportation potentially played a role in the divergence of heights as well. Komlos (1994) and Craig and Weiss (1998) suggest transportation improvements came with a cost. While the improvements allowed larger segments of the population to enjoy a more varied diet, food was less dense in nutrients on arrival. Northeastern states would have been at a nutrient disadvantage in spite of their expanded access to food. The development of transportation alternatives would have also spread disease to locations previously isolated from such sickness. The first appearance of cholera on a wide scale in the United States, in the 1830s, was spread through trade routes.

4.2. Negative Convergence Post Antebellum Period (1870-1890)

The period of negative convergence coincides with an increase in the commercialization of the South. Southern attention was diverted from food crops to cotton and increasing industrial activity, such as iron and textiles. Whereas, initially rural dwellers consumed nutrient-rich foods that were high in protein, especially animal products, commercialization induced farmers to focus more on market production at the expense of more diversified crop and livestock portfolios. Northern manufacturers began investing in southern mills in the 1880s to avoid dealing with higher-cost northern labor, and increasingly belligerent organized labor, and the number of cotton mills subsequently exploded. In 1880 there were 160 cotton mills in the south and by 1890, the region boasted over 400 cotton mills.[10] Similarly, the national interest in iron and coal spurred investment in the South and growth entered an explosive period in the 1880s that would extend into the next century.

The shift away from food crops had consequences. As noted, Komlos and Coclanis (1997) link the antebellum decline in stature to a rise in commercialization, most notably in areas switching to cotton from food crops and dairy cattle; more urban and commercialized areas compromised nutritional status across the board. Since refrigeration did not play a role in food preservation until after 1890 (Goodwin et al. 2002; Craig et al. 2004), a Southern shift to non-food crops meant a rise in the cost of obtaining dairy and meat products. Since the cost of these items is directly proportional to the distance from the closest production point, the increase in income would have been offset by the rise in prices of food for which they formally paid farm-gate prices. If the point of production for dairy products was too far away, then consumers could not buy the products at all. Southerners would have responded by substituting less expensive foods in their diet, most notably those rich in carbohydrates. A carbohydrate rich diet is less likely to provide the nutrients and protein needed to facilitate growth. If the diet was eaten for long periods of time, catch up growth would not occur and as a result adult stature would be affected. While the Komlos and Coclanis argument is directed toward the antebellum period, the continued rise in cotton production, cotton mills, and escalating growth of the iron industry in the South suggest it can be extended to the 1870-1890 period as well. Importantly, this effect impacted rural areas as well. The abandonment of self-sufficiency in food, even if just at the margin, appears to have been the key to the worsening of the biological standard of living in rural populations.

The relatively small decline in stature in the South in the antebellum period is more than likely attributable to the South's more heavily agricultural economy. Commercialization was beginning to take hold, but Southerners were still able to purchase food at lower costs than other regions (Komlos and Coclanis 1997). As the century progressed, the Southern emphasis continued to shift to cotton and commercial interests and less people were attracted to growing food crops. As agrarian interests waned, the point of food and beverage production began to move further from urban cores and costs to obtain these goods increased. The 1870-1890 period was one showing the decline of southern self-sufficiency manifesting itself through larger declines in stature, and here is a case in which the income effect worked against an improvement in the biological standard of living as Southern per capita income fell in the decades immediately following the war (Easterlin 1961).

Figure 6 is noteworthy for highlighting what at first glance appears to have been a puzzling midwestern height decline in the 1870-1890 period. The figure indicates the populations of several midwestern states had higher growth rate declines than those in the initially taller southern states. Negative convergence implies a taller state, such as North Carolina, would experience higher growth rate declines than a shorter midwestern state, such as Indiana. Figure 6 indicates the populations of several midwestern states had higher growth rate declines than those in the initially taller southern states. On average, the midwestern states experienced the largest height declines in the 1870-1890 period. The decline can be explained by rising income inequality, industrialization, and increasing urbanization.

Rising income inequality is known to exert a negative influence on height (Steckel 1983). If income is concentrated among the wealthy, income increases to this group will have little or no effect on their stature, as they are already achieving their genetically determined maximum. As Steckel (1995) notes, once growth is complete, a rise in income will not lead to additional stature improvements. Rising income inequality can more than offset the effect on height from rising incomes when the number of explanatory variables is expanded to include such factors as disease or diet (Fogel 1986). For instance, if only the wealthy are recipients of the income increases, the negative height effects of disease and diet among the poor will dominate the income effect on the heights of the rich, putting downward pressure on mean height.

Gregson (1996) suggests location-specific human capital contributed to increasing wealth and income inequality in the Midwest, and although she focuses on Missouri, the point applies more generally across the region. Early arrivers knew the strengths and weaknesses of growing specific crops and the best way to farm their existing crops. An early arriver need not imply a resident of 20 years. Gregson found that arriving only two years before another arriver generated higher mean wealth for the early arriver. The knowledge was valuable as they were able to select the best and most fertile land and rapidly accumulate wealth. Every migrant thereafter purchased inferior land at higher prices, thus detracting from their rents. In earlier work, Gregson (1993a and b) showed how the knowledge of heterogeneous soil types and terrain generated rents. The more diverse the land, the more diverse the crop mix, and the larger the rent extracted from the land. Therefore their location specific human capital maximized the rents they earned from the land and concentrated wealth to this select group, contributing to the rising wealth and income inequality in this region, as well as a diverse self-sufficient diet.

As the demand for small grains increased the relative price of wheat and oats, midwestern farmers were given an incentive to farm small grains. In the absence of refrigeration in shipping and storing of perishable animal products, overall nutrition would have suffered. Early arrivers would have known small grains can best be grown with certain types of soil using specific farming techniques and would have used this informational advantage more effectively than later arrivals (Gregson 1996). This was especially true for Midwestern states. The advantage for (or luck of) early arrivers is again evident, especially from 1860 to 1870, and further contributed to the increased wealth and income inequality in the Midwest. While wealth inequality in the rural Midwest was lower than it was for the nation in 1870, the early-arriver advantage made it feasible that wealth accumulation continued to work in favor of the early arrivers as during the key early decades of large-scale settlement. Gregson's human capital theory could explain part of the Midwest pattern in Figure 6, as the wealth gap between early and late arrivers would have continued to widen and, at the margin, contribute to the mean stature declines in the Midwest.

It is also conceivable that industrialization, as represented by, say, the rise of the coal industry as it contributed to the pattern. The coal industry is good proxy for late nineteenth-century industrialization as it underwent remarkable growth in the last quarter of the nineteenth century and was concentrated in certain geographic areas. As railroads expanded trade opportunities, investors sought to increase the number of coalfields to take advantage of the boom. From 1870-1890 coal production increased over 300 percent.[11] The coal industry contributed to rising aggregate output and incomes, but the coal industry boom was accompanied by a host of negative externalities. Environmental and health concerns related to the coal industry so familiar to today's reader were well recognized at the time, as noted by *Atlantic Monthly* columnist James Parton's oft-repeated description of coal-consuming

Pittsburgh in 1868 as "hell with the lid taken off" (cited in Gugliotta 2000). The burning of coal produces sulfur oxide and carbon dioxide, both of which are considered environmentally offensive.

The upper and middle classes were able to choose to live away from coal mining and processing areas, and thus the poorer segments of society bore the brunt of the environmental pollution. In Pennsylvania, the leading coal producing state in 1889, working-class men suffered from consistent smoke inhalation and had the highest death rates from acute respiratory disease (Gugliotta 2000). The negative health externalities generated by increased coal production would have hindered the growth process of children and contributed to the decline in mean height over the time period 1870-1890. Among the poorest segment of society, increased environmental pollution and its associated diseases would have negatively influenced the body's ability to allocate nutrients for growth. When the body is more susceptible to disease or sickness, net nutritional status suffers and the amount of nutrients available for growth diminishes. Table 5 shows the leading coal producing states in 1889. Five of the states are in the present sample and include Pennsylvania, Illinois, Ohio, Alabama, and Indiana. Note three out of the five are midwestern states.

To the extent the negative effects of industrialization on the biological standard of living overwhelm the income effect, coal production, as a proxy for industrialization, would be expected to have a negative effect on the growth rate of height in the 1870-1890 time period. A cursory look at the means gives support to the theory as heights in coal producing states declined twice as rapidly as non-coal producing states. Adding the variable to the conditional convergence regression as an explanatory variable can more formally test the theory. Specifically the variable is constructed as the growth rate of coal production per capita over the time period 1870-1890.[12] The results (Table 6) indicate the coefficient on the coal production dummy variable is negative and statistically significant and aids in explaining much of the variation in the growth rate of height. This finding offers insight into the unexpected magnitude of the midwestern height decline as two of the notable outliers, Illinois and Ohio, were leading coal-producing states in 1889.

Finally, the 1870-1890 period was also one of increasing urbanization for the Midwest. While the northeastern and southern region's share of the top 100 largest cities in this time either fell or stayed the same, the Midwest's share increased. For instance, in 1870, Chicago's urban population was 298,977 and ranked fifth among the largest U.S. urban places. By 1890 Chicago's urban population more than tripled to 1,099,850, placing it second only behind New York City. Table 7 shows the percentage increase in urban population among the Midwestern cities ranked in the top 100 largest urban cities and their 1890 ranking.[13] Notice the share of the urban population more than doubled for nearly every Midwestern city. The negative relationship between height and urbanization would help explain the large declines in the growth rates of height, as the area was urbanizing at a rapid pace.

Overall, the average height decline demonstrated by the negative convergence results in Figure 6 in the 1870-1890 time period can be explained by increased commercialization in the South, increased income inequality in the Midwest, industrialization as proxied by the leading coal-producing states in 1889, and the rapid urbanization of the region.

4.3. Convergence at the end of century

In terms of convergence, height and income patterns begin to coincide at the end of the nineteenth century. The positive conditional convergence found in Figure 9 implies a negative correlation between the growth of heights and the initial height. For instance, after controlling for geographic location, the populations in the shortest states grew faster than those in the initially taller states. The diffusion of and practical applications from the germ theory, improved (i.e. more hygienic) living conditions, and the adoption of refrigeration in the shipping and storing of perishables played a major role in improving average height as the body had less demands placed on it by disease and poor environmental surroundings and more nutrients were available for growth. Craig et al. (2004) directly estimate refrigeration's positive impact on stature after its widespread adoption in shipping (after 1880) and storage (after 1890), and Logan (2006) finds that by the late 1880s diets were quite balanced. Note that timing of the results in these studies correspond with the increase in stature across the United States, and the convergence across states.

Barro and Sala-i-Martin (1991) found the same type of convergence when examining income in the late nineteenth century and throughout most of the twentieth century. States with initially lower levels of income had higher per capita growth rates than their wealthier counterparts. The convergence between economic and biological indicators suggests income can be used to accurately describe the overall economic climate as the economy entered a more advanced stage of development. Eventually society's mastery of the germ theory, and the various manifestations of this mastery in the form of clean public water supplies and sewer system among other things, overcame the negative externalities associated with urbanization and industrialization. Thus in the twentieth century (and hopefully beyond) continued modernization was associated with improvements in biological indicators of the living standard – at least in the early developing countries like the United States.

5. Summary

Human stature reflects the effects of economic activity on the human body during the body's developmental years. It is most beneficial when studied in the context of a developing economy because it is capable of demonstrating the physical costs to populations as their economies move through the development process. This distinguishes height from the immediately recognizable standard of living measures such as income and output. Income paints only a partial picture, since it assumes general well being can be inferred from mean or aggregate purchasing power alone.

A developing economy should be represented by both material and biological measures: a reflection of both purchasing power and health. The divergence of income and height measures demonstrates this dynamic, as the general rise of incomes over the nineteenth century came at the expense of both health and nutrition and ultimately height. The decline in average height establishes an opportunity to explore the points of departure between height and income measures.

In order to clarify this difference, we have applied the concept of convergence to the study of stature. Convergence describes the evolution of average height differences across U.S. states during the nineteenth century. It seeks to clearly define stages of the development path by focusing on the changing magnitude of height differences between short and tall populations. The development path identifies three stages of the United States in the late nineteenth century: divergence, followed by negative convergence and ultimately positive convergence.

Divergence is evidence of increasing inequality and suggests states with shorter populations are not catching up to states with taller populations. The initial divergence in the early decades of the nineteenth century can be attributed to the urban-rural difference as well as improvements in transportation. Living and working close together increased the possibility of spreading disease in urban populations. As the nutrient source shifted towards less fresh, processed foods and beverages in urban areas, net nutritional status suffered, leading to diminished height. While the transportation improvements allowed larger segments of the urban population to enjoy a more varied diet, food was less dense in nutrients on arrival and created a new outlet for spreading disease to locations previously isolated from such sicknesses. The divide between urban and rural populations and the expansion of consumption choices afforded by the increase in incomes resulted in an increasing gap between short and tall populations.

Negative absolute convergence implies states converged to a lower, common steady state level of height with initially taller states, such as the Midwestern and Southern states, experiencing larger growth rate declines than the more urban Northeastern states. The height gap between short and tall populations decreased, but both populations were getting shorter. As Southern attention was diverted from food crops to cotton, flue-cured tobacco, and industrial production, net nutritional status was compromised as prices of protein-rich sources such as dairy and meat began to rise and populations began substituting cheaper, more carbohydrate-rich food. The carbohydrate rich diet is less likely to provide the nutrients and protein needed to facilitate growth and contributed to the decline in mean height. The second stage of development reveals the ubiquitous effects of industrialization as it extends its influence to the initially taller, rural populations. As they were previously isolated from industrial activity, their declines in mean height are greater than that of populations that had become urban or began urbanizing earlier in the nineteenth century.

The positive convergence at the end of the nineteenth century resulted from the mastery of the germ theory and improved living conditions – including refrigeration, personal hygiene, and reduced physical demands at work. As the body had less demands placed on it by disease and environment, more nutrients were available for growth. The end of the century marked the convergence between economic and biological standard of living measures and suggests income can be used exclusively to describe the economy as it enters a more advanced stage of development.

Curiously, this pattern is similar, though not identical, to what John Komlos has found in the Habsburg Monarchy in the nineteenth and early twentieth centuries, where heights diverged before 1870 or so, and converged thereafter. The standard of living measures, both biological and economic, offer two distinct and opposite accounts of the 19th -century economic development. The goal is not to drive out the notion of well being inferred from income trends, but to supplement it with biological information embedded in the regional height data. The evolution of height and reflects the biological costs associated with increased economic activity and income associated with development.

Table 1: Comparison of National Average Height Estimates (Height in Inches)

Year	Weighted Average	U.S. Actual Average	Difference
1800	68.02	68.07	-0.05
1810	67.65	68.11	-0.46
1820	68.02	68.07	-0.05
1830	68.27	68.31	-0.04
1840	67.78	67.80	-0.02
1850	67.37	67.36	0.01
1860	67.09	67.17	-0.08
1870	67.40	67.40	0.00
1880	66.72	66.73	-0.01
1890	66.38	66.57	-0.19
1900	66.15	66.93	-0.78

Source: Steckel (1995).

TABLE 2: Testing for Absolute Convergence (by estimating β in Equation 2), Over 20-Year Periods in 26 States

Dependent Variable: Growth Rate in Average Adult (white) Male Height

	1820-1840	**1830-1850**	**1840-1860**	**1850-1870**	**1860-1880**	**1870-1890**	**1880-1900**
Log of Height 1820	.0116*** (0.001)						
Log of Height 1830		0.0115 *** (0.002					
Log of Height 1840			0.008 * (0.004)				
Log of Height 1850				0.034 *** (0.011)			
Log of Height 1860					0.017 (.013)		
Log of Height 1870						-0.01*** (0.003)	
Log of Height 1880							-0.012 (0.004)
Observations	26	26	26	26	26	26	26
R-Square	0.65	0.36	0.10	0.20	0.06	0.29	0.007

* Indicates significance at the 10 percent level

** Indicates significance at the 5 percent level

*** Indicates significance at the 1 percent level

TABLE 3: Contrast of Antebellum Income and Height Estimates

Year	Real GDP per Capita ($1840)	Percentage per annum GDP Growth	U.S. Average Height	Percentage per annum Average Height Growth
1800	78	-	68.07	-
1810	82	0.51	68.11	.00588
1820	84	0.27	68.07	-.00587
1830	90	0.72	68.31	.03526
1840	101	1.13	67.80	-.07466
1850	111	0.93	67.36	-.06490
1860	135	1.95	67.17	-.02821

Source: Weiss (1992), as reported in Haines et al. (2002).

TABLE 4: Absolute and Conditional Convergence Regressions

Dependent Variable, Growth Rate in Average Height

	Conditional Convergence	Absolute Convergence	Conditional Convergence	Conditional Convergence
	1860-1880	**1860-1870**	**1870-1880**	**1880-1900**
Log of Height in 1860	0.003 (0.008)	0.046* (0.026)		
Log of Height in 1870			-0.012* (0.006)	
Log of Height in 1880				-0.011*** (0.004)
Southern Dummy Variable	.001** (.0001)		0.0004** (0.0002)	0.0004*** (0.0001)
Observations	26	26	26	26
R-Square	0.76	0.11	0.22	0.37

Table 5: Leading Coal Producing States, 1889

State	Coal Production (thousands of tons)
Pennsylvania	81,719
Illinois	12,104
Ohio	9,977
West Virginia	6,232
Iowa	4,095
Alabama	3,573
Indiana	2,845

Source: United States, Bureau of the Census (1913, Table 4, p. 187).

TABLE 6: Conditional Convergence Regressions
Dependent Variable, Growth Rate in Average Height, 1870-1890

	Growth Rate 1870-1890
Log of Height in 1870	-0.001875*** (0.00336)
Coal Production Per Capita	-0.0026* (0.00138)
Southern Dummy Variable	0.0004163*** (0.000095)
Observations	26
R-Square	0.6649

TABLE 7: Increasing Urbanization of the Midwest

State	City	Percentage Increase in Urban Population	1890 Urban Ranking (out of 100 cities)
Illinois	Chicago	367.87%	2
	Peoria	130.94%	71
	Quincy	179.54%	96
Ohio	Cincinnati	137.31%	9
	Cleveland	281.54%	10
	Columbus	281.86%	30
	Toledo	257.83%	34
	Dayton	200.90%	45
Missouri	Saint Louis	145.33%	5
	Kansas City	411.39%	24
	St.Joseph	267.44%	55
Michigan	Detroit	258.71%	15
	Grand Rapids	365.17%	47
Indiana	Indianapolis	218.55%	27
	Evansville	232.51%	56
	Fort Wayne	199.76%	86
Kentucky	Louisville	59.92%	20
	Covington	52.50%	82

Source: Calculated from United States, Bureau of the Census (1872 and 1892-1898).

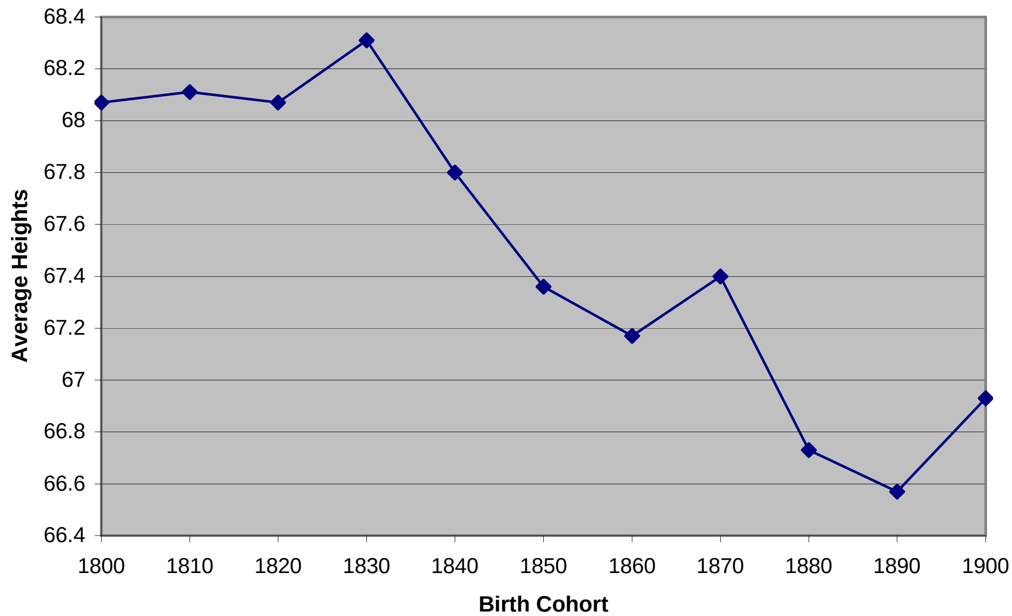

Figure 1
U.S. Average Heights: 1800-1900
Source: Steckel (1995)

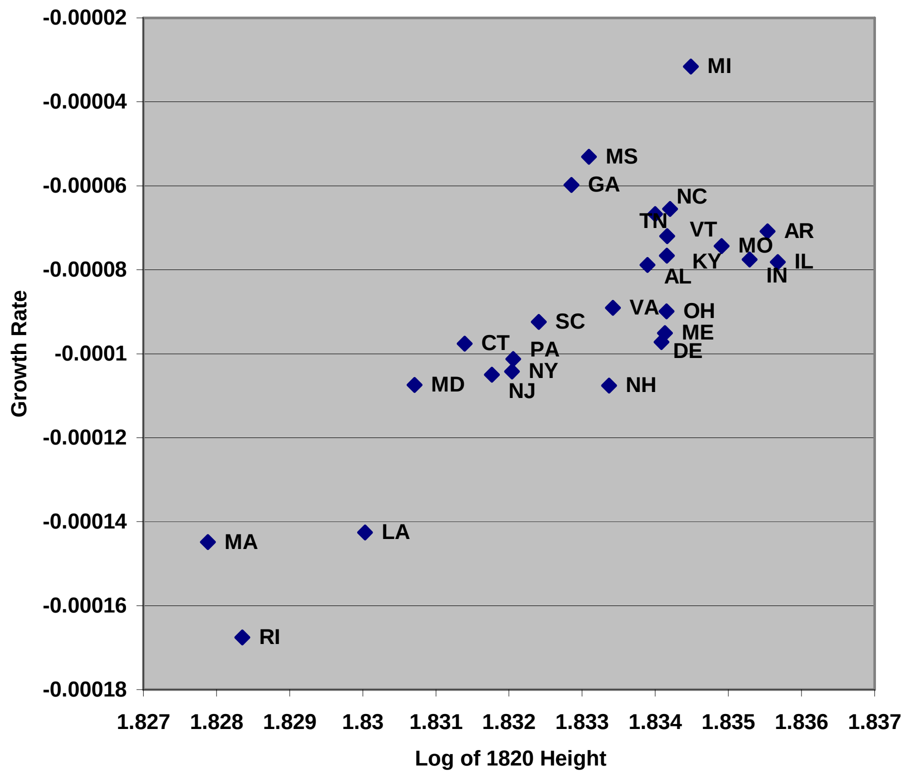

Figure 2
Absolute Divergence 1820-1840

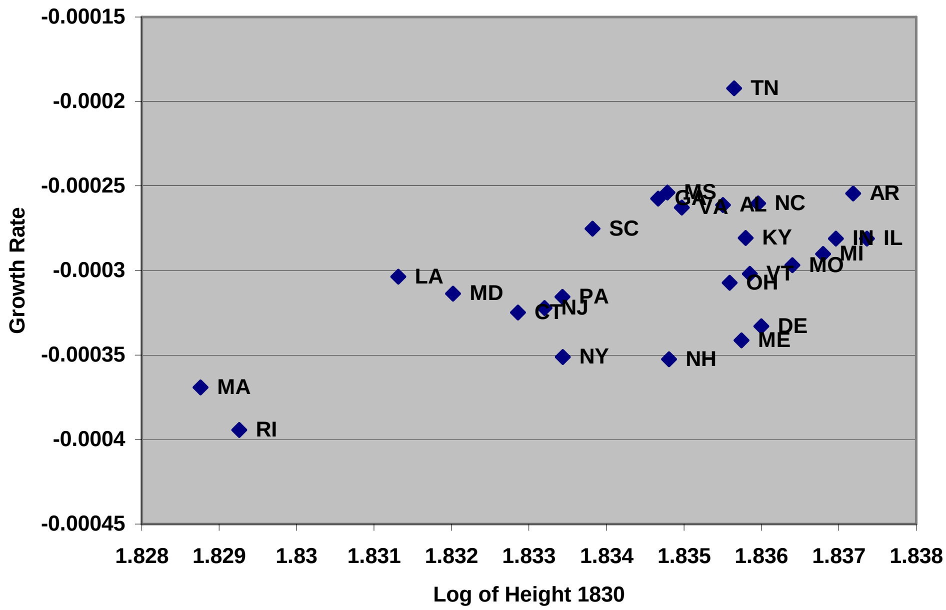

Figure 3
Absolute Divergence 1830-1850

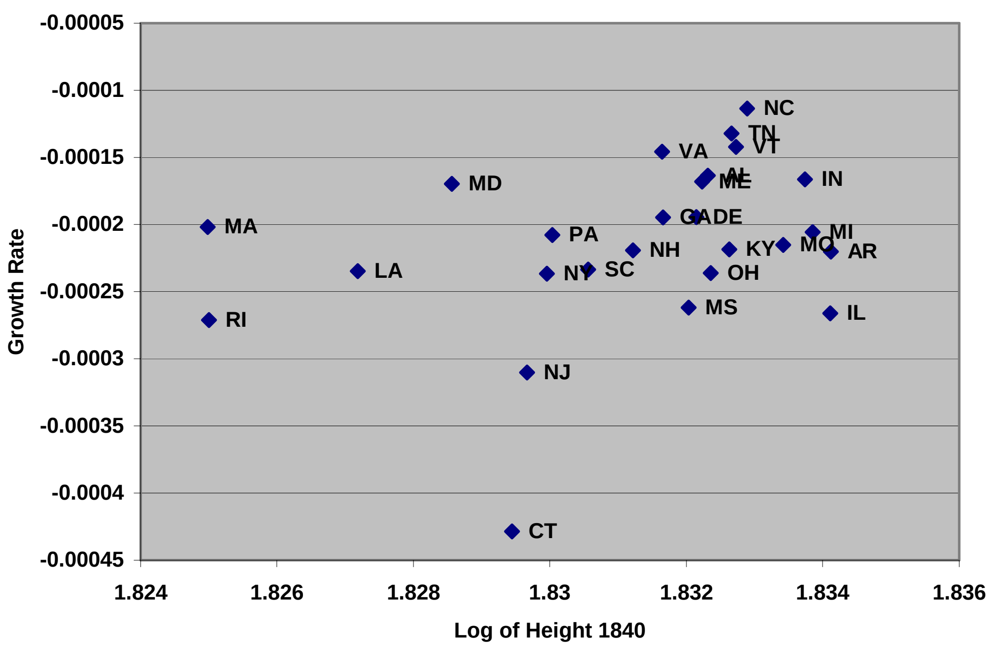

Figure 4
Absolute Divergence 1840-1860

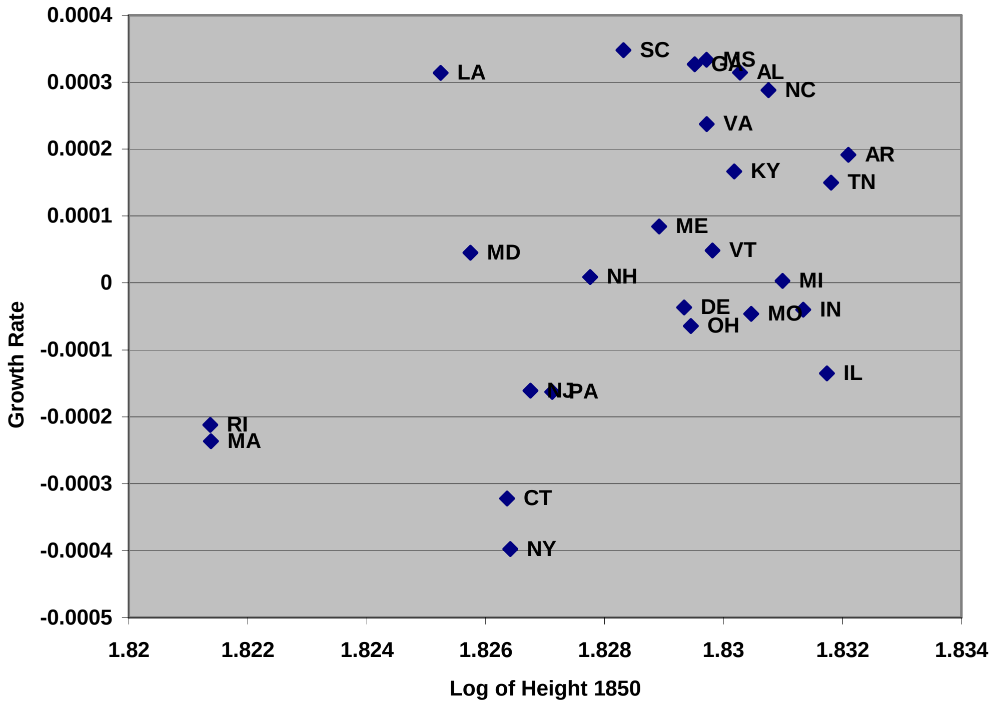

Figure 5
Absolute Divergence 1850-1870

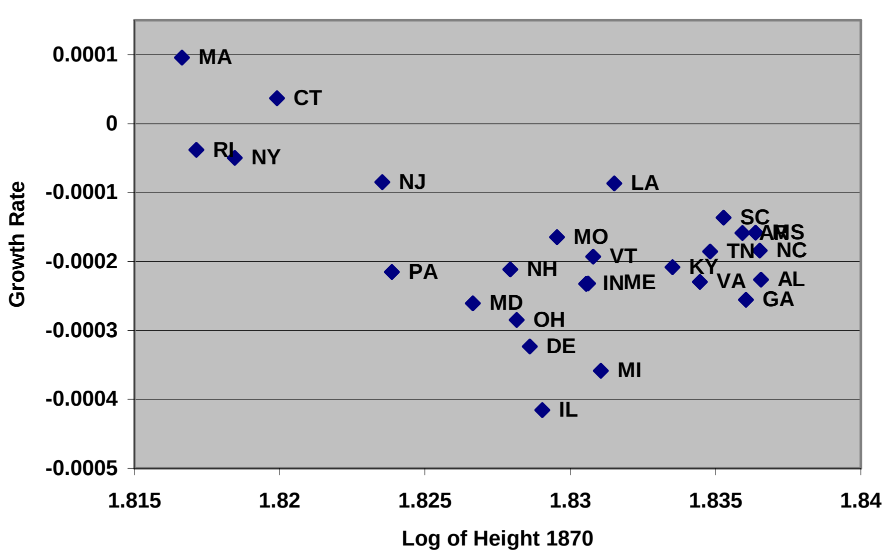

Figure 6
Negative Absolute Convergence 1870-1890

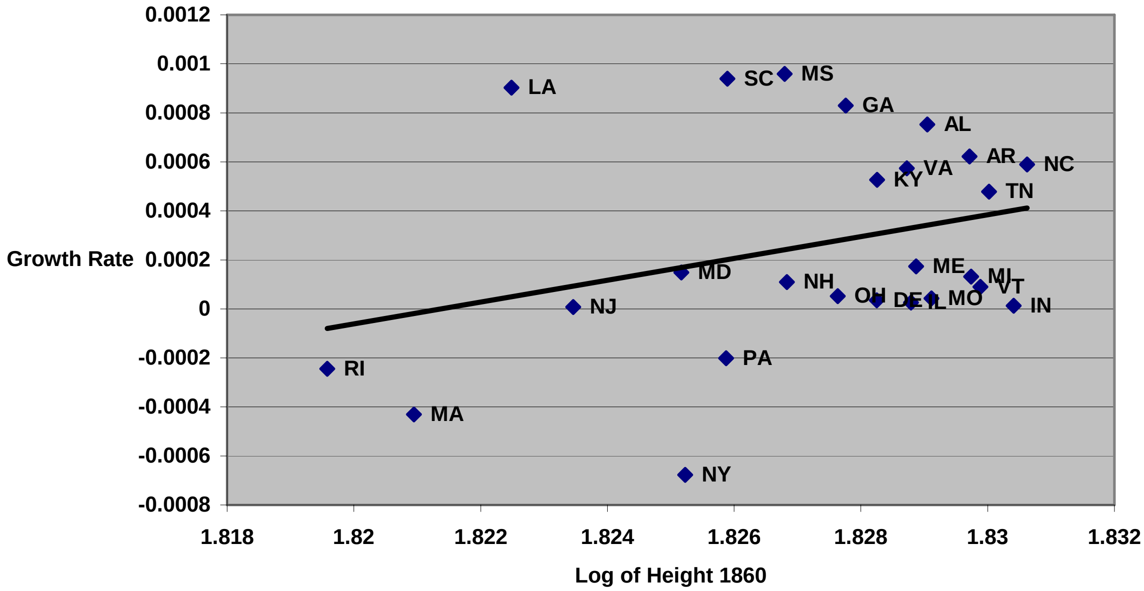

Figure 7
Absolute Divergence 1860-1870

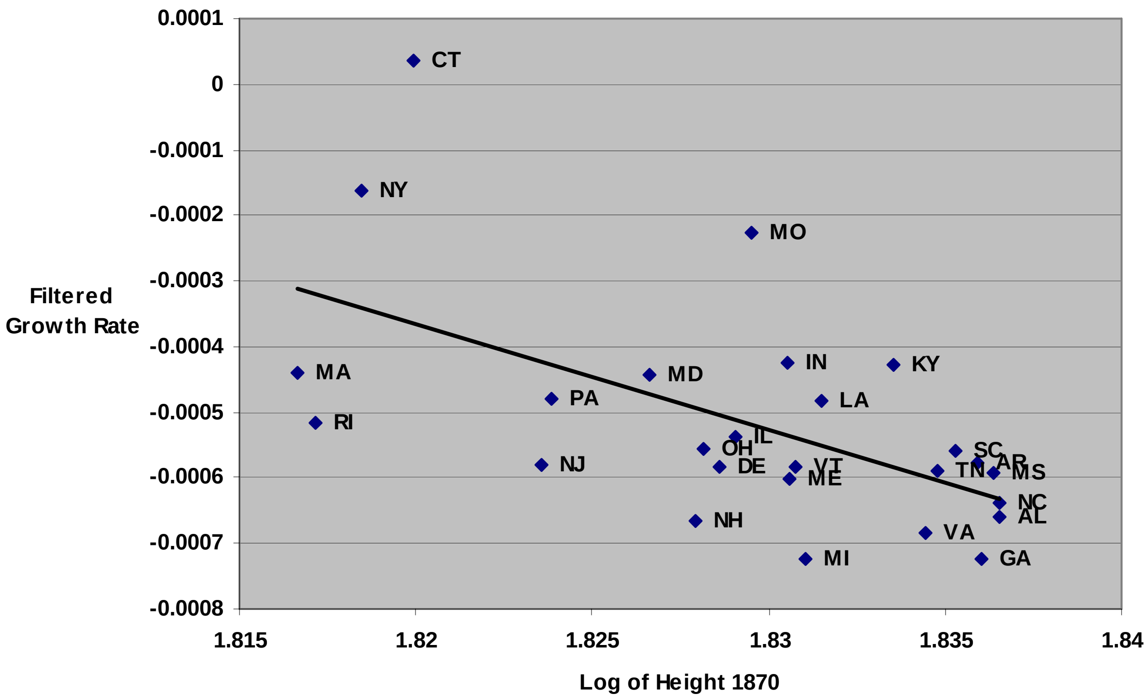

Figure 8
Conditional Convergence 1870-1880

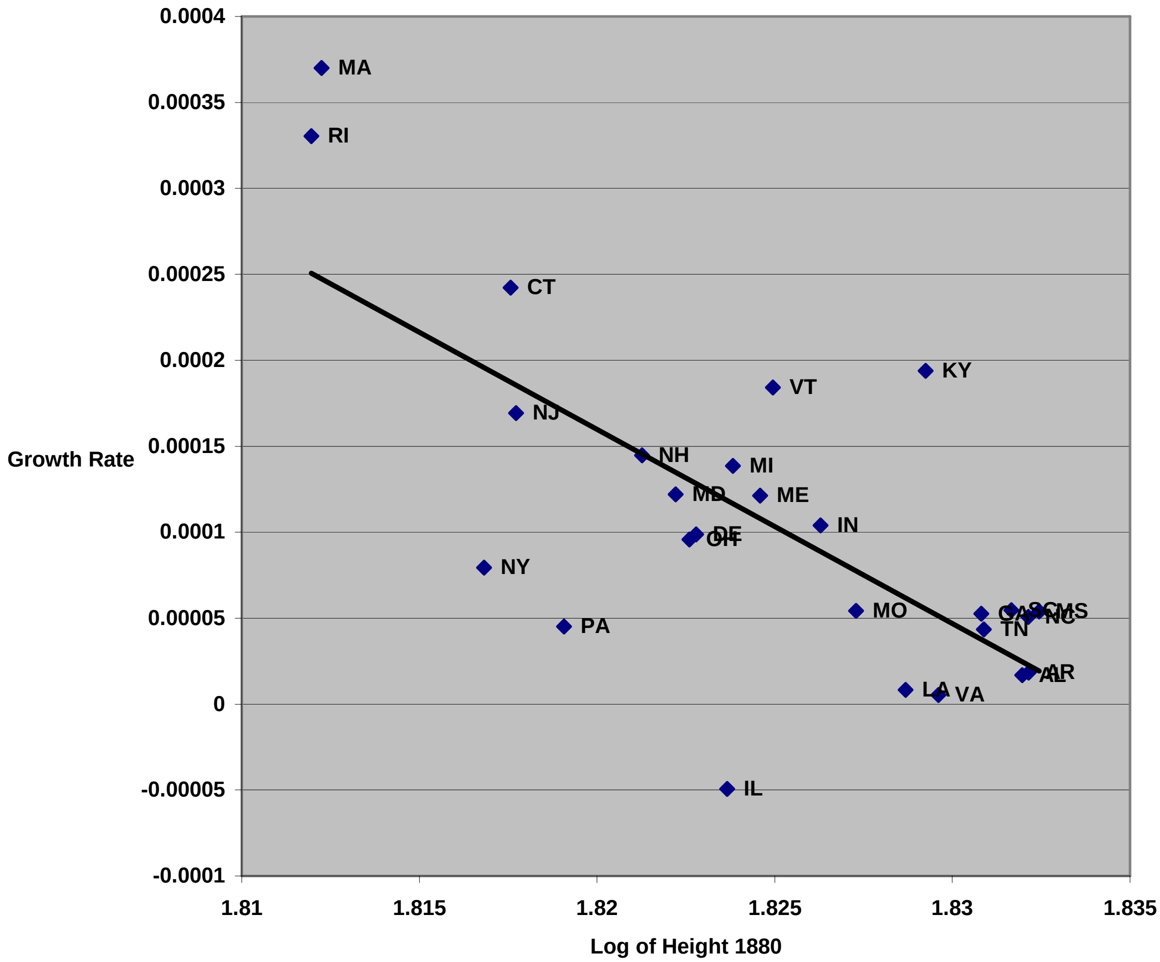

Figure 9
Conditional Convergence 1880-1900

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Appendix

The state-level estimates of mean adult stature were derived by inverting a technique developed by Craig and Weiss (1998) and Haines et al. (2003) to estimate the height of individuals. The base data consist of a sample of Union Army recruits from data originally collected by Fogel, Engerman et al. (ICPSR). They include recruits born in the nineteenth century for whom information was available on, among other things, place of birth and adult height. Following Craig and Weiss (1998) and Haines et al. (2003), observations on individual (white) adult male heights were estimated based on the underlying economic relationship between adult stature, net nutrition, and the economic environment in which the recruit matured. The basic equation, as estimated by Craig and Weiss is:

$$HEIGHT = \alpha + \beta_1 MOVER + \sum_{j=1862}^{1865} \beta_{2j} YEAR_j + \beta_3 NUTRITION + \beta_4 WEALTH + \beta_5 TRANSPORT + \varepsilon$$

HEIGHT is the height in inches of the *ith* Union Army recruit. MOVER is a dummy variable, which takes the value one if the recruit enlisted in a county other than the one in which he was born, zero otherwise. $YEAR_j$ is one if the recruit enlisted in the *jth* year, zero otherwise. NUTRITION is the marketable surplus of protein production in the county in which the recruit spent infancy. WEALTH is the sum of agricultural and industrial wealth per capita in the recruit's county. TRANSPORT is one if the county was on a navigable waterway, zero otherwise. Haines et al. adjusted this basic framework by adding a labor force variable, FARMER, which equals one if the individual was a farmer, zero otherwise; HINDEX, an index for the concentration of agricultural production in the county in which the recruit was born; URBAN, the proportion of the county's population residing in an urban area; and CDR, the county's crude death rate.

Since we are estimating mean height at the state level, we have dropped the YEAR and TRANSPORT variable. We also dropped HINDEX and CDR, because we did not have comparable state-level data for the entire nineteenth century. That leaves us with the MOVER, NUTRITION, FARMER, WEALTH, and URBAN variables. We calculated each of these variables at the state level from various primary and secondary sources. We then transformed each variable by subtracting the national mean from it. Thus we have:

$$HEIGHT = \mu + \alpha DMOVER + \beta DNUTRITION + \gamma DFARMER + \delta DWEALTH + \phi DURBAN$$

Where HEIGHT is the mean adult (white) male height in the *ith* state for birth cohort born in year *t*; μ is the mean U.S. height in year *t*; DMOVER is the difference between the proportion of the resident population not born in the *ith* state and proportion of the U.S. population not born in the United States in year *t*; DNUTRITION is the difference between the marketable surplus of protein produced in the *ith* state and U.S. production in year *t*. DFARMER is the difference between the agricultural share of the labor force in the *ith* state and the U.S. share in year *t*. DWEALTH is the difference between the sum of agricultural and industrial wealth per capita in the *ith* state and U.S. wealth in year *t*. DURBAN is the difference between the proportion of the population residing in an urban area in the *ith* state and U.S. proportion in year *t*. The coefficients α, β, γ, δ, and φ are taken from column 1 of Table 7 in Haines et al. (2002, p. 407).

The estimated heights, by birth cohort, are reported in Table A. Note that only 26 states had complete time series dating back to 1820, and thus they are the only ones used in the regression analysis above. Of course the estimates assume that the relationship estimated by Craig and Weiss and Haines et al. was stable across the century. While this is clearly a strong assumption, note that at the bottom of the table, we compare a linear combination of estimated heights (weighted by population) to the U.S. average. Until the end of the century, differences are quite small by almost any reasonable standard. However, at the end of the century the relationship begins to breakdown. The most problematic variable was URBAN. The relationship between urbanization and height is highly non-linear, and for the five most urban states, we had to decrease the weight on the URBAN variable at the end of the century. Although there are data for certain populations, for some states, for some years (see for example Komlos 1987; Steckel 1995; and Sunder 2003, 2005), the estimates reported in Table A are for all native-born white males born in year *t*. For consistency we have used the estimated figures even when a sub-sample might have been available.

Appendix Table A
Mean Height in the United States,
White Adult Males, by State,
by Birth Cohort, 1800-1900

	1800	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900
Alabama[1]	N.A.	N.A.	68.22	68.47	67.97	67.65	67.46	68.64	67.91	67.93	68.50
Alaska	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Arizona[3]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.83	66.39	65.70	65.52
Arkansas[1]	N.A.	N.A.	68.48	68.74	68.25	67.94	67.56	68.54	67.94	68.04	68.53
California[3]	N.A.	N.A.	N.A.	N.A.	N.A.	67.23	67.00	66.65	65.40	65.02	65.16
Colorado[3]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.90	65.87	65.56	65.76
Connecticut[1,2]	67.86	67.89	67.83	68.05	67.52	67.04	66.20	66.06	65.70	66.17	66.44
Delaware[1]	68.28	68.34	68.25	68.55	67.94	67.51	67.34	67.39	66.49	66.40	66.80
Florida	N.A.	N.A.	N.A.	68.44	67.96	67.70	67.38	68.53	67.60	66.77	67.88
Georgia[1]	68.03	68.11	68.05	68.34	67.87	67.53	67.26	68.56	67.73	67.75	68.43
Hawaii	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Idaho[3]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	68.01	66.94	66.46	66.49
Illinois[1]	N.A.	N.A.	68.50	68.76	68.25	67.88	67.42	67.46	66.63	66.18	66.48
Indiana[1]	68.42	68.47	68.44	68.70	68.19	67.82	67.67	67.69	67.03	66.97	67.35
Iowa	N.A.	N.A.	N.A.	N.A.	68.30	67.91	67.72	68.07	67.05	66.96	67.03
Kansas	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.75	68.05	67.40	66.69	67.19
Kentucky[1]	68.27	68.31	68.26	68.52	68.02	67.64	67.34	68.16	67.49	67.51	68.10
Louisiana[1]	N.A.	67.59	67.61	67.81	67.17	66.87	66.45	67.84	67.40	67.57	67.96
Maine[1]	68.20	68.26	68.25	68.51	67.96	67.44	67.43	67.70	66.77	66.98	67.14
Maryland[1]	67.82	67.82	67.72	67.92	67.38	66.95	66.86	67.09	66.41	66.29	66.78
Massachusetts[1,2]	67.40	67.35	67.28	67.42	66.83	66.28	66.21	65.56	64.90	65.85	66.02
Michigan[1]	N.A.	68.47	68.31	68.67	68.21	67.76	67.57	67.77	66.65	66.66	67.08
Minnesota	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.69	68.13	66.79	66.32	66.73
Mississippi[1]	68.08	68.15	68.09	68.36	67.93	67.56	67.11	68.61	67.99	68.11	68.69
Missouri[1]	N.A.	N.A.	68.38	68.61	68.14	67.68	67.47	67.54	67.19	67.03	67.35

	1800	1810	1820	1830	1840	1850	1860	1870	1880	1890	1900
Montana[3]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.39	66.48	66.32	66.68
Nebraska	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.75	67.94	67.38	66.81	67.00
Nevada[3]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.32	66.65	66.49	66.85
New Hampshire[1]	68.60	68.13	68.13	68.36	67.80	67.26	67.12	67.29	66.26	66.63	66.71
New Jersey[1,2]	68.62	67.98	67.88	68.11	67.56	67.11	66.60	66.61	65.72	66.35	66.24
New Mexico	N.A.	N.A.	N.A.	N.A.	N.A.	67.76	67.77	68.36	67.70	66.09	66.82
New York[1,2]	67.88	67.94	67.93	68.15	67.60	67.05	66.87	65.83	65.59	65.68	65.83
North Carolina[1]	68.26	68.32	68.27	68.54	68.06	67.73	67.71	68.63	67.94	68.05	68.63
North Dakota	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.26	65.85	66.20	67.05
Ohio[1]	68.28	68.32	68.26	68.48	67.98	67.52	67.24	67.32	66.47	66.44	66.76
Oklahoma	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Oregon	N.A.	N.A.	N.A.	N.A.	N.A.	67.47	67.33	67.99	66.97	65.41	66.54
Pennsylvania[1]	67.97	68.00	67.93	68.14	67.61	67.16	66.97	66.66	65.93	66.00	66.07
Rhode Island[1,2]	67.38	67.38	67.35	67.49	66.84	66.28	66.01	65.63	64.86	65.52	65.85
South Carolina[1]	67.86	67.92	67.98	68.21	67.70	67.35	66.97	68.43	67.87	68.01	68.57
South Dakota	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	66.69	65.48	66.67	67.15
Tennessee[1]	68.21	68.28	68.23	68.49	68.02	67.89	67.61	68.36	67.75	67.78	68.41
Texas	N.A.	N.A.	N.A.	N.A.	N.A.	67.73	67.35	68.69	67.57	67.00	67.91
Utah	N.A.	N.A.	N.A.	N.A.	N.A.	67.88	67.76	68.39	66.78	65.41	66.34
Vermont[1]	68.20	68.26	68.26	68.53	68.03	67.58	67.59	67.73	66.83	67.13	67.40
Virginia[1]	68.19	68.24	68.14	68.39	67.86	67.56	67.41	68.31	67.55	67.59	68.09
Washington	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.37	68.01	67.04	64.71	66.34
West Virginia	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	68.22	67.47	67.62	68.01
Wisconsin	N.A.	N.A.	N.A.	N.A.	68.14	67.72	67.57	67.77	66.86	66.58	67.02
Wyoming	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	67.43	66.76	66.60	66.96
Weighted Average	68.02	67.65	68.02	68.27	67.78	67.37	67.09	67.40	66.72	66.38	66.15
U.S. Ave. Actual	68.07	68.11	68.07	68.31	67.8	67.36	67.17	67.40	66.73	66.57	66.93
Difference	-0.05	-0.46	-0.05	-0.04	-0.02	0.01	-0.08	0.00	-0.01	-0.19	-0.78

Notes: [1]States used in regression analysis. [2]Urban variable has been adjusted for 1890 and 1900. See text for details. [3]Estimates for 1890 and/or 1900 have been smoothed. None of these states were included in the regression analysis.

[1] The idea can be traced to Ramsey (1928).

[2] Steckel (1995) notes improvements in stature stemming from increases in income are not unlimited. Once growth is complete, further increases in income will not lead to additional stature improvements. Furthermore, there is a biological maximum to the mean stature of a population, and for those populations enjoying a surplus of nutrients, further consumption would merely lead to obesity in the absence of increased physical activity.

[3] This puzzle was not unique to the United States. The populations of Great Britain, the Netherlands, and Germany, among other early industrializing countries, experienced similar declines in stature (see Drukker and Tassenaar 1997; Floud and Harris 1997; and Komlos 1998).

[4] To put this in a modern context, for example, the United Nations Human Development Index includes longevity (expectation of life at birth), knowledge (literacy and schooling), and the standard of living (as measured by per capita GDP). In the United States during the nineteenth century, this index would have unambiguously increased at the same time human stature was decreasing. Becker et al. (2005) include longevity in their overall assessment of cross-country inequality. They find that including longevity in their convergence regressions yields evidence of convergence not apparent in earlier studies. Unfortunately, measures of longevity by state in the 19th-century United States are currently unavailable.

[5] Steckel (1995) finds a statistically significant and inverse relationship between height and the percent of the population that was urban in the mid-nineteenth century.

[6] Refrigeration played an important role in food preservation, but only after 1890 (Craig et al. 2004).

[7] Although the time period is somewhat arbitrary, with decennial data, the choice is limited.

[8] The dummy variable takes on the value one for the following southern states: Virginia, Arkansas, South Carolina, Georgia, Tennessee, Alabama, Mississippi, North Carolina, and Louisiana; zero otherwise.

[9] All equations have been estimated with constant terms that are not reported in the table.

[10] http://us.history.wisc.edu/hist102/weblect/lec02/02_02.htm

[11]United States, Bureau of the Census (1922, Tables 8 and 9, pp. 258 and 260), as reported at: http://www.eh.net/encyclopedia/article/adams.industry.coal.us.

[12] 1.0 was added to all observations to the coal production per capita variable to avoid the problem of taking the logarithm of zero for some observations.

[13] There are six Midwestern states in the present sample: OH, IL, IN, MO, MI, and KY. Percentages computed from 1870 and 1890 U.S. censuses.