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Heights and Living Standards of English Workers During the Early Years of Industrialization, 1770–1815

STEPHEN NICHOLAS AND RICHARD H. STECKEL

We employed data on the heights of English and Irish male convicts transported to Australia to assess the living standards of workers between 1770 and 1815. Falling heights of urban- and rural-born males after 1780 and a delayed growth spurt for 13- to 23-year-old boys revealed declining living standards among English workers during the Industrial Revolution. This conclusion was supported by the fall in English workers' heights relative to that of convicts transported from Ireland. Significant urban-rural and regional variations in English living standards were revealed by using regression techniques.

The last decade has seen a substantial research effort directed toward measuring the trend in real wages and living standards during the British Industrial Revolution.¹ Although most historians agree that workers received real-wage improvements from the 1820s on, controversy still surrounds the changes in English workers' living standards before that decade. Advising the standard-of-living pessimists to retreat to the pre-1820 era, Peter Lindert and Jeffrey Williamson argued that their data on male earnings pointed to real-wage stability between 1755 and 1797, then falling real wages until 1819, broken only by a brief rise between 1810 and 1815.² Taking issue with Lindert and Williamson's cost-of-living index, N. F. R. Crafts thought that pre-1820 real wages of all blue-collar workers possibly grew somewhat faster than consumption per head.³ But consumption expenditures showed retarded growth during this period, and per capita levels of food consumption actually fell.⁴ The emerging "consensus" view is that real-wage growth for all blue-collar workers increased in line with overall personal consumption, which grew only very slowly.⁵ The pessimists' case, if there is one, can be found between 1770 and 1825.

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¹ For a summary see Crafts, "Real Wages."

² Lindert and Williamson, "English Workers' Living Standards," pp. 10–12.

³ Crafts, "English Workers' Real Wages"; and Crafts, *British Economic Growth*, pp. 90–99.

⁴ Crafts, *British Economic Growth*, p. 40; and Jackson, "Growth and Deceleration in English Agriculture," pp. 334–51.

⁵ Crafts, "Real Wages," p. 79.

Among regional studies, L. D. Schwarz discovered falling real wages in London between 1750 and 1770 and between 1780 and 1800, and generalized London's experience to those regions of England that shared a similar pattern of handicraft production.⁶ The regional character of industrialization was also identified in Nicholas von Tunzelmann's measures of the differential impact of Lancashire and the south on the national real-wage trend, and Crafts as well as Lindert and Williamson cautioned that industrialization was geographically uneven and that regional consumption patterns differed greatly across England.⁷ Not only did living standards vary regionally, but wage rates and living standards varied between sections of the working class, creating working-class winners as well as losers even during periods of falling real wages.⁸

Since then E. H. Hunt and W. Botham have taken issue with Schwarz's, Lindert and Williamson's, and Crafts's claim that wages fell "everywhere" between 1755 and 1810 and that slow growth meant that the Industrial Revolution marked no real "discontinuity" in the late eighteenth century.⁹ Using a series of north Staffordshire male wages, Hunt and Botham found that real wages increased before 1820 and speculated that those real-wage gains were typical of much of the north and midlands, as those regions experienced the stimulus of rapid industrialization even more strongly than did north Staffordshire.¹⁰ Accepting that Schwarz's estimates of London's wage movements held for the south, Hunt and Botham's wage data support E. W. Gilboy's conclusion that regional divergence, especially the north-south divide, was the outstanding characteristic of movements in money wages and the standard of living of the working classes in eighteenth-century England.¹¹ However, though they underscore the importance of regional variations in living standards, the north Staffordshire wage series do not reinstate the old view of marked discontinuity in British growth.

After a decade of research on real-wage trends, our knowledge of pre-1820 living standards can at best be termed "tentative," leading Crafts to call for "a substantial effort to augment the existing database on wages and prices."¹² Anthropometrics offers an alternative to real wages as a method for assessing changes in living standards in the 1770-to-1820 period. Roderick Floud, Kenneth Wachter, and Annabel Gregory have led the way in the analysis of British height data, collecting information on 108,000 army recruits between 1750 and 1880

⁶ Schwarz, "The Standard of Living," pp. 34–36.

⁷ von Tunzelmann, "Trends in Real Wages," pp. 39–40; Crafts, *British Economic Growth*, p. 107; and Lindert and Williamson, "English Workers' Real Wages: Reply to Crafts," p. 149.

⁸ Williamson, *British Capitalism*, p. 8; and Crafts, *British Economic Growth*, pp. 105–6.

⁹ Hunt and Botham, "Wages in Britain," pp. 382–97.

¹⁰ *Ibid.*, pp. 385–88.

¹¹ Gilboy, *Wages in Eighteenth Century England*, p. 224.

¹² Crafts, "Real Wages," p. 90.

and similar data on adolescent boys from the Marine Society of London and the Royal Military Academy at Sandhurst.¹³ Correcting for the truncation problem associated with minimum height requirements that varied by regiment, birth cohort, and age group, Floud and his colleagues found that the long-term or secular trend in average height of 24- to 29-year-old military recruits was upward for birth cohorts of 1750 to 1840, then downward until the 1870s before turning upward again.¹⁴ For birth cohorts of the 1760-to-1820 period, the army data show a downward trend from a 1760s peak to a 1790s trough, then a strong upward trend until the 1820s, when average height once again fell. This pattern of mean height also held for 18-year-old recruits, 21- to 23-year-old recruits, and for poor London boys recruited into the Marine Society.¹⁵ The average height of 24- to 29-year-old army recruits increased over 2 inches (from 65.84 to 68.02 inches) for soldiers born between 1792 and 1822 and by up to 4 inches for Marine Society recruits born after 1800, pointing to rapidly rising living standards.¹⁶ Army recruits born in 1810, for example, were the tallest men in the sample, almost an inch taller than early twentieth-century soldiers. Early industrialization was not simply benign: by this measure of stature it brought widespread improvements in workers' living standards.

This article provides an alternative interpretation of living standards for English workers during the early (1770 to 1815) industrialization period, using data on the height of 11,303 men tried in English courts and transported to the penal colony of New South Wales, Australia, between 1817 and 1840. We first briefly outline our methodology and survey our data source. In the second section we provide descriptive measures of the height profile of English workers and a measure of changes in English workers' living standards during the crucial period (1770 to 1815). We then discuss regression results that allow for composition effects such as age, occupation, and location on English workers' heights, and finally use height to test for regional differences in living standards.

METHODOLOGY AND DATA

Research on height by economic historians has proliferated in the past 15 years.¹⁷ The common motivation that binds together this growing field of work is the need for improved measures of living standards in the

¹³ Floud, Wachter, and Gregory, *Height, Health and History*.

¹⁴ *Ibid.*, pp. 136–38.

¹⁵ *Ibid.*, pp. 136–38, 165–66.

¹⁶ *Ibid.*, p. 171.

¹⁷ See the following studies for methodological details: Trussell and Steckel, "The Age of Slaves"; Steckel, "Slave Height Profiles"; Steckel, "Peculiar Population"; Steckel, "Growth Depression and Recovery"; Fogel et al., "Secular Changes"; and Floud et al., *Height, Health and History*.

past. Underpinning this line of investigation are studies by human biologists, anthropologists, and nutritionists that establish the reliability of anthropometric measures as indexes of health and nutrition. Height for age, the change in height between successive ages (velocity or rate of growth), the age at which final height is reached, and final adult height “reflect accurately the state of a nation’s public health and the average nutritional status of its citizens.”¹⁸ Although genetic conditions could also affect growth, the common genetic pool of our English and Irish convicts means that environmental factors were dominant in our questions of changes in stature.¹⁹

In interpreting stature as a measure of living standards, it is important to recognize that height is a net rather than a gross measure of nutrition. Height depends on the nutrition available for physical growth after the claims made by body maintenance needs, illness, and work. An individual’s ability to generate a surplus for growth depends on the body’s efficiency at nutrient utilization, on the intensity of work performed, on the disease environment, and on the state of public health. Despite the large number of factors that may influence stature, average height has been found to be highly correlated with the log of per capita income in a sample of developed and developing countries.²⁰

Our sample comprised 11,303 English and, for comparative purposes, 5,005 Irish male convicts transported to New South Wales between 1817 and 1840. In all, some 160,000 convicts were sent to Australia (of whom about 16 percent were female), including roughly 80,000 men transported to New South Wales from the First Fleet in 1788 to the end of transport in 1840. Accompanying each convict ship was an indent, a document that contained complete information on each convict, including age, gender, occupation, conjugal status, literacy status, town and county of birth, crime and previous convictions, as well as height. The fine grid of height measurements and the accompanying detailed information bolster our confidence in the accuracy and reliability of the convict records. A survey of the trial records of 596 of our transported convicts tried in the London Central Court revealed that over 98 percent of the sentences and crimes recorded there corresponded with those in the indents. Although the court records only listed information on occupations for 3.5 percent of the 596 men surveyed, all of that fraction agreed with those in the indents. The indents recorded over 1,000 separate occupations, with a level of accuracy and detail far superior to

¹⁸ Eveleth and Tanner, *Worldwide Variation*; and Fogel et al., “Secular Changes,” p. 3.

¹⁹ For a further discussion of genetics and growth see Eveleth and Tanner, *Worldwide Variation*; and Tanner, *Foetus into Man*.

²⁰ Steckel, “Height and Per Capita Income.” The correlations are 0.84 to 0.90, depending on the age and sex of the population. These high correlations suggest that factors correlated with poverty—such as poor diet, hard work, and poor medical care—are the major sources of nutritional deprivation and slow growth.

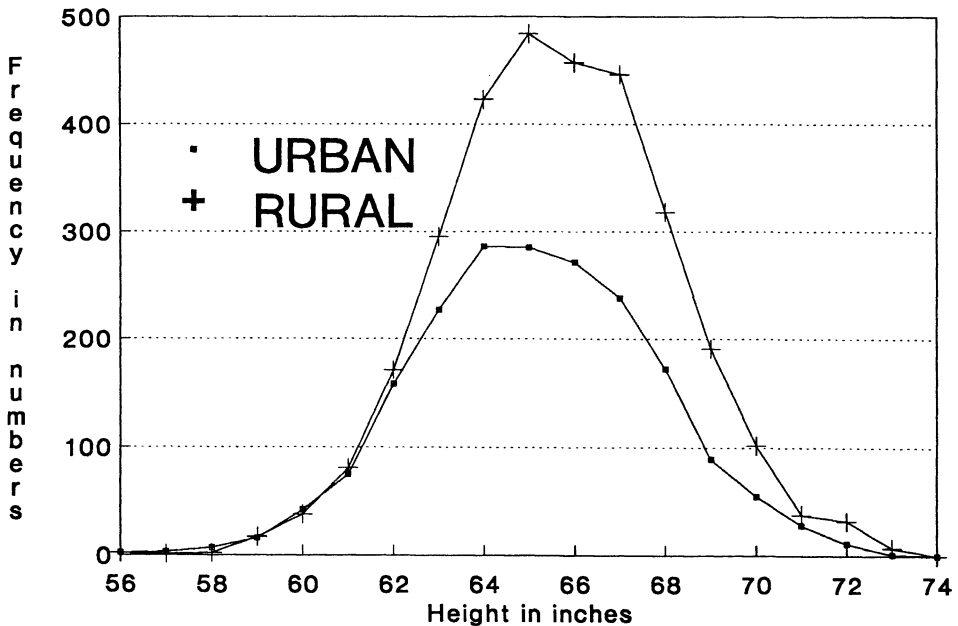


FIGURE 1

HEIGHT FREQUENCY FOR URBAN AND RURAL MALE ENGLISH WORKERS
(23 TO 49 YEARS)

that in the contemporary census. Cross-tabulations of county of trial with occupations were consistent with a priori expectations: most cutlery makers were tried in Sheffield, knitters and stocking makers in Nottingham, and potters in Staffordshire.²¹ There were no significant changes in the proportion of convicts born in the various counties of England between 1817 and 1840. Comparing the distribution of the convicts' origins with that of the English population in 1831 and 1841 showed that most convicts came from the heartland of England. Cornwall, Devon, and Dorset in the south and Northumberland, Cumberland, Westmoreland, Yorkshire, and Durham in the north were underrepresented relative to the whole population, whereas Middlesex and Warwick were overrepresented.

Height was typically recorded to the nearest quarter-inch, and the frequency distribution in Figure 1 shows little sign of "heaping," which would indicate careless procedures or a disinterest in accuracy. Given the Jarque-Bera tests shown in Table 1, we cannot reject the hypothesis that the distribution of male English and Irish height is normal, or Gaussian.²² The absence of truncation bias is a desirable feature of our height data, given that the alternative source of English male heights,

²¹ Nicholas and Shergold, "Convicts as Workers," pp. 63–68.

²² The Jarque-Bera statistic tests whether the first four moments of the sample distribution are consistent with the normal distribution. See Jarque and Bera, "Efficiency Tests for Normality."

TABLE 1
JARQUE-BERA TEST FOR NORMALITY ON SAMPLE OF CONVICTS

Sample	Jarque-Bera (X^2 Critical Value = 5.19)
English males	3.48
English urban males	2.21
English rural males	2.24
Irish males	2.01
Irish urban males	1.88
Irish rural males	1.99

Source: *Convict Indents*.

TABLE 2
SKILL CLASSIFICATION OF ENGLISH WORK FORCE AND
ENGLISH TRANSPORTED CONVICTS
(in percentages)

Armstrong Classification	English 1841 Census (Male Only)	English Convicts (Male Only)
1. Professional	1.7	0.3
2. Intermediate	9.2	3.1
3. Skilled	47.9	45.6
4. Semiskilled	25.7	26.3
5. Unskilled	15.5	24.7

Sources: Great Britain, *1841 Census*; and *Convict Indents*.

the British army records, is contaminated by minimum-height standards that erode the lower tail of the distribution and complicate the interpretation of the data.

Before attempting to interpret average heights, we must consider the possibility that the individuals measured did not represent the entire population about which we would like to draw inferences. For example, data based on army volunteers are biased because they typically included proportionately more individuals from the lower classes. One way to address this problem of selectivity is to compare characteristics of the sample with those of the entire population. Having done so, we can assert that the convict sample was broadly representative of the English working classes. First we coded the occupational structure of the convict sample and the 1841 English census, using Armstrong's skill-social class scheme: (1) professional, (2) intermediate, (3) skilled, (4) semiskilled, and (5) unskilled.²³ As shown in Table 2, the major difference between the English work force and the convict sample was that over three times as many English workers as convicts fell into Armstrong's classes 1 and 2. However, the proportion of skilled and semiskilled convicts corresponds very closely to that in the English

²³ Armstrong, "Use of Information About Occupations."

TABLE 3
MALE CONVICT LITERACY RATES

	Read and Write (%)	Read Only (%)	Illiterate (%)	Sample Size
Total	51.3	22.6	26.1	7,761
Rural	45.3	26.4	28.3	4,666
Urban	56.1	22.9	21.0	3,095

Source: *Convict Indents*.

population. A Spearman's rank correlation between 83 occupations identified in both the 1841 census and the convict indents was 0.714, suggesting a close match between the sample occupations and those of the English work force.

From 1827 on, the indents included whether each transportee could both read and write, read only, or neither read nor write, thereby providing us with an alternative measure of literacy to the signature test in marriage registers (Table 3). The indent data on literacy was also superior to that in the marriage registers because it gave information on rural versus urban birthplace and on occupation. Urban-born workers were more literate than the rural-born and 81 percent of the skilled workers, but 71 percent of the semiskilled and only 65 percent of the unskilled workers were literate.²⁴ Compared with the registrar-general's average literacy level of 58 percent for England between 1824 and 1827 and Roger Schofield's estimate of about 63 percent from a random sample of 274 English parish registers between 1790 and 1820, the male convicts were more literate than the working population at home.²⁵ Of course the two measures of literacy are not identical, as the marriage register data involved a direct test of literacy and applied to the whole population. But the high level of literacy of the transportees is confirmed by comparisons with army recruits and other convicts. Recruits into the British army were less literate than the general population before 1880, and only 65 percent of Webb's sample of 23,172 male and female English prisoners between 1837 and 1839 were literate.²⁶ In a sample of politically conscious prisoners involved in a rising in the manufacturing districts of Lancashire, Cheshire, and Stafford, R. K. Webb found that 73 percent were literate—almost exactly the same as the rate (74 percent) for male convicts transported from those same counties. A rank correlation of 0.92 between M. Sanderson's sample of literacy by occupations for Lancashire in the 1830s and the convict sample provides additional evidence for the robustness and representativeness of our data.²⁷

We also assessed the representativeness of the convict sample by comparing the transported convicts with offenders left at home. Recent

²⁴ Nicholas and Nicholas, "Male Literacy."

²⁵ Schofield, "Dimensions of Illiteracy"; and Registrar General, *Annual Report*.

²⁶ Webb, "Working Class Readers," p. 335; and Floud et al., *Height, Health and History*, p. 110.

²⁷ Sanderson, *Education, Economic Change and Society*, pp. 11–16.

work by historians of crime has rejected the idea of a separate nineteenth-century criminal or dangerous class, born and bred to a life of crime and operating as organized gangs.²⁸ These studies argue that the great majority of crime was committed by ordinary men who worked at jobs in the normal fashion but who also stole articles on occasion. Though not “honest men,” the convicts were employed people who supplemented their income by theft in times of distress. There can be little doubt that our transportees were typical of such British criminals. Compared with offenders in Warwickshire, transported convict workers had a similar occupational breakdown: 58.8 and 53.4 percent unskilled and semiskilled, 38.4 and 43.6 percent skilled, and 2.8 and 2.9 percent middle and upper class, respectively. They had committed the same types of offences: less than 3 percent were against persons; the rest were property offences, the great majority of them larceny.²⁹ The rank correlation between the occupations of the transported male convicts and the male prisoners held in British jails in 1841 was 0.908. On the basis of these tests, it seems fair to argue that the convicts transported to Australia were coincident with the broad skill–social class mix of the English working class.

PROFILE AND TIMING OF CHANGES IN HEIGHT

The growth spurt, final attained height, and age at terminal height presented in Figure 2 and Table 4 are sensitive measures of the environmental impact on individuals’ well-being.³⁰ Both terminal height and the peak in the growth spurt occurred at about the same age for English rural and urban workers, but it was more vigorous for rural workers. This rural-urban differential for the whole period reflected in Figure 2 and Table 4 was also present when the sample was broken into pre-1790 and post-1790 subsamples. Our rural-urban distinction was based on whether a man gave his birthplace as a city or a town; it is a measure of birth location superior to that employed by Floud, Wachter, and Gregory, who used whether a recruit came from an urban or a rural county.³¹ The rural advantage was most pronounced between the ages of about 14.5 to 17, and at maturation the rural-born were 0.5 inch taller than their urban counterparts, a statistically significant difference. The peak in the growth spurt between the ages of 14 and 15 for both groups

²⁸ Rude, *Criminal and Victim*; Jones, *Crime, Protest, Community and Police*; and Philips, *Crime and Authority*.

²⁹ Philips, *Crime and Authority*, pp. 141–67.

³⁰ Aggregating people across the time periods required to attain average height by age for Figure 2 hides the temporal diversity in the data, but it is hoped that the cohort effect is self-canceling. In checking for this we found that the growth spurts for urban and rural men born after 1795 retained the same basic profiles as those in Figure 2, giving us confidence in our growth trajectories.

³¹ Floud et al., *Height, Health and History*, p. 202.

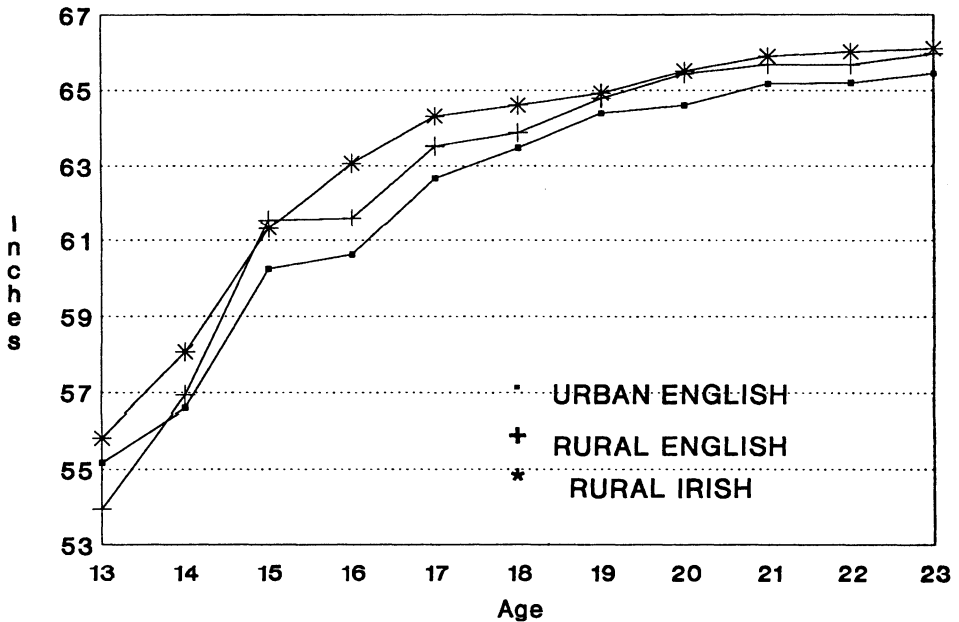


FIGURE 2

AVERAGE HEIGHT BY AGE OF ENGLISH AND IRISH WORKERS

TABLE 4
TERMINAL HEIGHT AND *t*-TEST OF DIFFERENCES IN TERMINAL
HEIGHTS OF CONVICTS

	English	Rural English	Urban English	Irish	Rural Irish	Urban Irish
Height (in inches)	65.76	65.96	65.44	66.03	66.10	65.82
English		3.61*	4.82*	5.25*	5.20*	0.63
Rural English			7.12*	1.07	1.94	1.39
Urban English				7.87*	8.16*	3.57*

* = significant at the 5 percent level

Source: *Convict Indents*.

was a year later than that for well-nourished children today.³² Because the adolescent growth spurt requires large additional nutritional requirements, the one-year delay in adolescent growth may imply some measure of early childhood malnutrition, retarded food intake, or increased work loads relative to dietary allotments for Industrial Revolution children. In addition, male workers continued to grow until they were 23, well beyond the modern standard, in which final height is attained by about 18. The centiles of modern growth attained by the convict workers, shown in Table 5, suggest that a catch-up occurred during the last four years of growth for urban and rural workers alike.

³² Eveleth and Tanner, *Worldwide Variation*, p. 165.

TABLE 5
CONVICT WORKERS' CENTILES OF MODERN HEIGHT

Rural English				
Age	Height	Number	Standard Deviation	Centile
13	53.94	4	2.79	
14	56.94	16	2.19	1.0
15	61.56	61	3.04	3.4
16	61.61	48	2.72	0.6
17	63.52	75	3.08	2.4
18	63.87	209	2.25	3.0
19	64.78	342	2.16	6.3
20	65.43	431	2.44	10.0
21	65.67	417	2.42	11.7
22	65.67	453	2.53	11.7
23	65.96	3,113	2.50	14.1
Urban English				
Age	Height	Number	Standard Deviation	Centile
13	55.17	19	3.66	2.0
14	56.60	53	2.88	0.7
15	60.25	155	3.06	1.2
16	60.62	199	2.71	0.2
17	62.68	254	2.46	1.1
18	63.47	390	2.32	1.8
19	64.39	516	2.22	4.7
20	64.60	505	2.24	5.0
21	65.17	448	2.59	8.4
22	65.19	408	2.53	8.5
23	65.44	1,966	2.56	10.1

Source: *Convict Indents*; and Tanner, Whitehouse, and Takaishi, "Standards."

In terms of international comparisons, English workers were better nourished than German peasants of the late 1700s, the poor in Italy in the 1870s, and nineteenth-century American slaves during adolescence (but not at maturity). Although the average English Industrial Revolution worker was shorter than white Americans and Stuttgart aristocrats in 1800, rural workers were about as well off as the Stuttgart middle class at the end of the eighteenth century.³³ The height of English workers, then, compared favorably with other eighteenth- and nineteenth-century workers. But their lower achievement relative to modern height standards and the later maturation of males during the Industrial Revolution confirms hard times during early childhood or adolescence or both for rural and urban workers. The significantly shorter stature of urban males meant that Englishmen born in the country were taller, fitter, and probably (all else being equal) more productive than those born in the city. Besides using the standards of modern populations—

³³ Steckel, "Peculiar Population," pp. 730–31.

that is, continental Europeans and North Americans in the eighteenth and nineteenth centuries—the height of English Industrial Revolution workers can be compared with that of men born in Ireland. Ireland, predominantly rural and agricultural, was a part of the British economy that remained relatively untouched by the forces transforming the industrializing regions in England. Using a subjective index of impoverishment, Mokyr and Ó Gráda found that the Irish poor became poorer before 1850, yet the average height of Irish recruits into the Royal Navy and the East India Company army who were born before 1815 was about half an inch greater than British recruits.³⁴ Our data show that Irish convicts were approximately a quarter-inch taller than English convicts (see Table 4), a statistically significant difference consistent with Mokyr and Ó Gráda's results on stature.

These data provide new insights into English as well as Irish economic progress. Final heights of English workers, either rural or urban, were not significantly different from those of rural Irish workers, but their growth profiles were (see Figure 2). Although the sample sizes for convicts under 16 years of age were small, it seems that the Irish had a head start on the timing of the growth spurt and a more vigorous spurt than the English from about the age of 15. During their whole adolescent growth period, rural Englishmen were considerably shorter (more than an inch at 16) than rural Irishmen, a gap not significantly narrowed until the age of 19. The comparison for urban Englishmen is even more dramatic. At 16, English urban workers were 2.5 inches shorter than rural Irishmen, and their final attained height was significantly less than that of Irish workers.

This suggests that, during the vital growth spurt years, rural Irishmen were either better nourished than Englishmen or faced different work demands and environmental conditions than did urban English workers. Insofar as Ireland serves as a useful “control” economy, rural Englishmen were much better insulated from industrial changes than were urban British workers, who bore more of the brunt of industrialization than did their rural countrymen.

The Irish height advantage appears inconsistent with evidence that per capita income was lower in Ireland than in England. Because comparisons of many countries indicate that income is one of the important determinants of stature, an interesting research problem arises whenever these measures disagree to a substantial extent.³⁵ However, per capita income is merely an approach to living standards—as are stature, real wages, literacy, and life expectation at birth. Obviously, care should be taken in using any one of these as an index of the other. The problem illustrated by this case is that income is not the

³⁴ Mokyr and Ó Gráda, “Poor and Getting Poorer?,” p. 227; and Mokyr and Ó Gráda, “Heights of the British and Irish.”

³⁵ Steckel, “Height and Per Capita Income.”

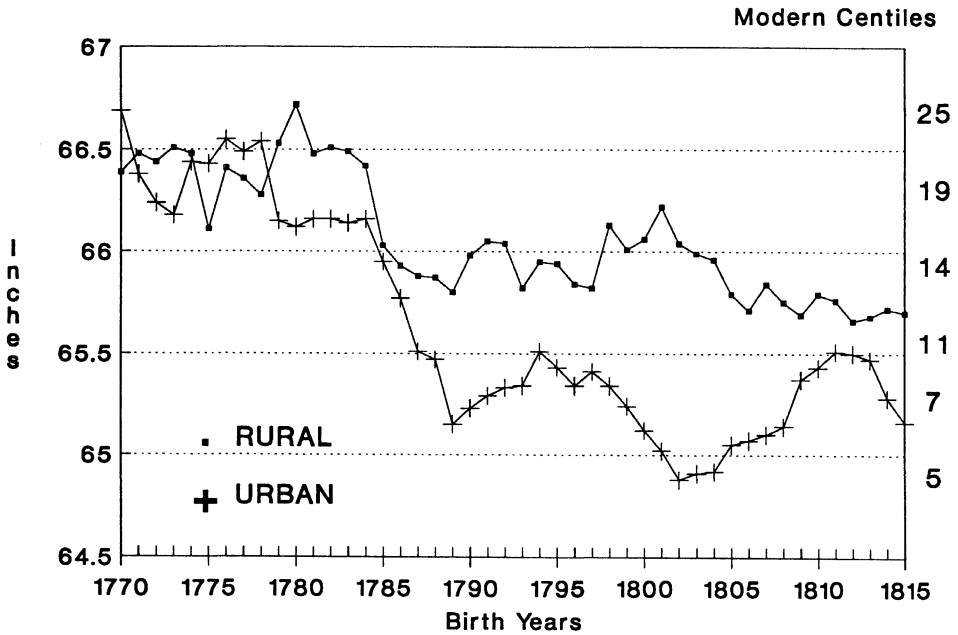


FIGURE 3

HEIGHT PROFILE OF ENGLISH WORKERS 23 TO 49: 5-YEAR MOVING AVERAGE

only determinant of average height; others are exposure to infectious diseases (and therefore public health measures, population density, and standards of personal hygiene), the distribution of income, work effort, and the quality of the diet. Therefore the evaluation of the possible explanations will require a thorough study of the social and economic history of both regions.

It was in the cities and towns, the pessimists argued, that the living standards of ordinary working-class Britons fell most sharply during the early years of the Industrial Revolution. Moving averages of final attained urban and rural height by year of birth provide a sensitive indicator of the changing living standards of urban and rural workers. The five-year moving average of final attained height shown in Figure 3 is based on between 22 and 357 observations for each year between 1780 and 1815, but far fewer (an average of 12) observations in the 1770s. The figure displays the different pattern in the time trends of urban and rural heights, with urban height falling more steeply than rural heights—a pattern Floud and his colleagues also discovered in their data.³⁶

Although the heights of both rural and urban birth cohorts declined after 1780, rural height remained fairly stable between 1790 and 1804, averaging 66 inches before deteriorating during the last years of the Napoleonic wars. Meanwhile, urban height fell continually, except for a

³⁶ Floud et al., *Height, Health and History*, pp. 206–7.

weak comeback in the early 1790s and a somewhat stronger comeback between 1803 and 1811. The time profile of attained final height shows a fall in living standards for urban workers, who in 1802 were more than 1.25 inches shorter than birth cohorts born in 1780. As can be seen in the centiles on the right-hand scale of Figure 3, urban workers born in the 1770s were near centile 19, which corresponded to the Stuttgart aristocracy (at the 18.7 centile), but those born in 1800 had fallen to centile 6, which approached the level of Creole slaves in Trinidad in 1813. The rural birth cohorts also experienced declining living standards: they began the 1780s sharing the living standards of turn-of-the-century Stuttgart aristocrats but ended up at approximately centile 12, slightly worse off than the Stuttgart middle class.³⁷ The pessimists' case of deteriorating living standards is thus upheld for the pre-1820 period, particularly among the urban population.

Although there is no single powerful test of selectivity bias, the various tests reported hereafter put at risk the hypothesis that the decline in heights was an artifact of our data. Almost one-third of our convicts were tried in a county other than that in which they were born, but it is not possible to know whether the move occurred during childhood, adolescence, or after maturity. Assuming that all convicts who were tried in the same county as their place of birth were nonmovers, five-year moving averages of height for rural- and urban-born nonmovers showed the same profile as that for the whole sample. The convicts in our sample were convicted and transported after 1816, so those born in the pre-1790 period in Figure 3 were older than those born in the 1820s. The lower tail of the distribution for older men—those born before 1790—was not truncated, nor was the upper tail of the distribution overloaded, which would indicate twisting or distortion in the height distributions. We can also reject a possible period effect: that crime became concentrated in poorer and shorter men as the century progressed. Organizing the sample by year of conviction, the distribution of heights for convicts transported before and after 1833 was normal.³⁸

The environmental insult causing the sharp fall in final attained heights illustrated in Figure 3 was likely to have occurred during childhood, the years of adolescent growth spurt, or some combination of the two. Deficient food inputs, reflected in the higher prices of food relative to manufactured goods during that period, were caused by shortages and dislocations in food supplies resulting from the Napoleonic Wars and poor harvests. J. D. Mingay and E. L. Jones emphasized bad harvests due to the weather as the major cause of rising food prices, while M. Olson, G. Hueckel, J. Mokyr and N. E. Savin, and Jeffrey

³⁷ Steckel, "Peculiar Population," pp. 730–31; and Komlos, *Nutrition and Economic Development*.

³⁸ The Jarque-Bera statistic was 2.65 before 1833 and 1.26 after 1833.

Williamson focused on the continental blockade and war.³⁹ The number of harvest failures was significantly higher between 1790 and 1815 than either before or after, and weather was a significant factor in short-run price jumps in 1795, 1800, and 1812.⁴⁰ The Napoleonic wars, which closed or disrupted continental markets, increased the risks and uncertainty of international grain trade. Hueckel estimated that transport and transactions costs accounted for between 25 and 40 percent of the market price of wheat during those years.⁴¹ By the time young men born after 1780 had reached their final height, they had suffered sometime during their growth years from deficient food intake caused by poor harvests, war shortages, or both.

Because urban heights exhibited a different profile than did rural heights, the differences between the two data sets were unlikely to have been simply due to the differential impact of food supplies, though rural workers' access to food supplies meant they fared better than urban workers in times of shortage. Both the smaller average height of urban males and their different time profile relative to rural workers reflect the poorer health standards, substandard housing conditions, and overcrowding in Britain's cities. Although there were no major epidemics during this period, exogenous disease factors in Britain's growing towns and cities constrained urban height. How much of the sharp fall in and different profile of urban relative to rural height was due to disease, environment, congested living conditions, income irregularity, or greater work effort and how much to deficient food supplies is conjectural, but our urban height data identify a significantly greater fall in urban living standards than rural standards after 1780.

COMPOSITION EFFECTS

Before accepting the results shown in Figure 3 on the time profiles of stature, it behooves us to consider the possible influence of composition effects on the sample. We need to investigate the hypothesis that the height declines were an artifact of changing occupational structure over time. The Armstrong classification scheme was adapted to generate five broad occupational groups—unskilled, skilled, public service, domestic service, and professional/dealers—that were included in our regression equations as dummy variables. Dummy variables were also constructed for year of birth by five-year periods, with those born before 1780 comprising the excluded class. Data on literacy was not collected before

³⁹ Mingay, *The Agricultural Revolution*, p. 113; Jones, *Agriculture and the Industrial Revolution*; Olson, *Economics of Wartime Shortage*; Hueckel, "Relative Prices and Supply Response," pp. 401–14; Hueckel, "War and the British Economy"; Mokyr and Savin, "Stagflation in Historical Perspective"; and Williamson, *British Capitalism*.

⁴⁰ Olson, *Economics of Wartime Shortage*, p. 63; and Mokyr and Savin, "Stagflation in Historical Perspective," p. 224.

⁴¹ Hueckel, "War and the British Economy," p. 369.

1827; therefore, the inclusion of literacy in the regression models would have drastically decreased the sample sizes (from 1,951 to 1,037 for the urban-born), excluded all men born before 1780, and greatly reduced the number of men in the sample born before 1800. Because the profile of the five-year moving averages of urban and rural heights shown in Figure 3 were different, we ran separate regressions for convicts born in urban and in rural areas.

There is reason to believe that occupational height differences may have existed. Occupational choice was governed by comparative advantage as well as by environmental influences during the growing years. For example, taller individuals may have been attracted to jobs for which strength was an asset; smaller people may have sought positions for which size and strength were unimportant. To the extent that positive intergenerational correlations existed for the occupations of fathers and sons, the occupational categories may reveal income or wealth differences that affected proximate determinants of growth such as diet, housing, and work effort. If laborers tended to have fathers who were laborers, for example, their stature may inform us about the net nutrition of children from laboring families.

The regressions in Table 6 show that composition effects by occupation were comparatively unimportant. Individuals employed in public service, which included soldiers, were tallest among the occupational groups, particularly among rural residents. Military recruiters often imposed minimum height standards to achieve the size and strength important to their activities. Those employed in domestic service were the shortest, a phenomenon that might be explained by poverty during the growing years and by a comparative advantage of small size in that line of work. The other occupational groups (unskilled and skilled) were not significantly different from the omitted class (professionals and dealers). The time profiles of Figure 3 persist in the year-of-birth dummies but are slightly dampened after controlling for occupation. Among urban males stature was significantly lower (by about 0.8 inch) for those born in the early 1800s compared with the period before 1780. Among the rural population, which shows a flatter time profile in Figure 3 compared with those residing in urban areas, the cohort effects were important only late in the period; all coefficients for birth years 1805 to 1819 were negative and had t -values in excess of 1.1, but only that for 1810 to 1814 was statistically significant ($t = 2.02$). These results establish that the time pattern in Figure 3 is not an artifact of compositional factors.

For men born before 1790, both our convict data and the sample of British army recruits display a downward trend in height. After 1795 a puzzling divergent pattern emerges: army heights increased while convict heights fell. The 1807 and 1822 recruits born during the last years of war, harvest failure, and accelerating urbanization were the

TABLE 6
REGRESSION MODEL FOR COMPOSITION EFFECTS BY OCCUPATION

	Rural (Age 23+)	Urban (Age 23+)
Unskilled	0.154 (0.61)	0.200 (0.76)
Skilled	-0.008 (-0.03)	-0.344 (-1.44)
Public Service	1.383 (4.29)	0.083 (0.26)
Domestic Service	-0.440 (-1.46)	-0.487 (-1.64)
Born 1780-1784	0.433 (1.80)	0.212 (0.77)
Born 1785-1799	0.149 (0.75)	-0.383 (-1.76)
Born 1790-1794	-0.030 (-0.19)	-0.424 (-2.44)
Born 1795-1799	-0.029 (-0.19)	-0.487 (-2.73)
Born 1800-1804	0.157 (1.05)	-0.801 (-3.87)
Born 1805-1809	-0.154 (-1.12)	-0.785 (-4.13)
Born 1810-1814	-0.275 (-2.02)	-0.341 (-1.80)
Born 1815+	-0.234 (-1.42)	-0.812 (-3.52)
Constant	65.967 (243.73)	66.209 (248.02)
R^2	0.019	0.024
DW	1.97	1.85
Observations	3,100	1,951

Notes: The *t*-statistics are given in parentheses. DW indicates the Durbin-Watson test results.

tallest in the army sample. This is something of an anomaly, which Floud and his colleagues warned might reflect the uncertainties in the size of correction for underrepresentation of short recruits due to the minimum height standards.⁴² Questioning whether the “rapidity of the great height leap [between 1795 and 1825] should be taken at face value,” they tested their estimating procedure and speculated that offer bias (tall recruits making themselves available to the army in peacetime, when civilian demand for labor fell) might account for the very tall recruits around 1815.⁴³ Alternatively, the two samples might be reflecting different sections of the working class, especially if the army had come to rely on the unemployed, casual laborers, and those living in poverty. Whatever the cause for the different trends in the convict and army mean heights after 1795, our data show that the living standard fell before 1820.

⁴² Floud et al., *Height, Health and History*, p. 138.

⁴³ *Ibid.*, pp. 171, 190-91.

REGIONAL PATTERNS

Historians agree that living standards varied regionally but, as Schwarz's 1990 survey of the regional real-wage series showed, the local wage data are "insufficient to enable extensive generalizations."⁴⁴ Our height data, which are county- and urban/rural-specific, allow alternative tests of the regional patterns of living standards by assessing differences in final attained height for each county and regional area in England.

Figure 4 shows test results for a set of nested hypotheses regarding final attained height. In the most general regression model, at the top of the table, final attained height depends on whether an individual was born in an urban or rural part of a specific county; the model at the bottom predicts one height for all of England. Formally, the tests in Figure 4 show whether the coefficients on the additional variables in the more general models (but excluded from the less general models directly below) differ significantly from zero. If the coefficients in the more general model are not significant (that is, if the *F* value is less than the critical value in parentheses), we should proceed to the next, less general equation; when the coefficients in the more general model are significant, the model is supported. For example, the most general (interaction rural/urban county) model, which specified that final attained height depended on whether an individual was born in a rural or urban part of a particular county, was not supported. Also insignificant was the next-most-general model (the no-interaction model) shown at top right, in which height depended on the county of birth and whether the individual was born in an urban or rural location. The absence of significant differences in individual county net nutrition is not surprising, because employment, industrial, and wage-and-cost regimes spanned county boundaries.

Grouping counties into different regional areas, we tested a region-specific model, based loosely on Hunt's agricultural wage areas: London and the home counties, the south, midlands, north, and fringe (including Cornwall, Devon, Cumberland, Westmoreland, and Northumberland).⁴⁵ The preferred model is the interaction region-specific model, in which height depended on whether a man was born in a rural or urban part of a particular region. Table 7 presents data on average height for each region, with London and the home counties having the shortest men. The men from the south and the midlands were taller than those from London and the home counties but shorter than those from the fringe and the north. The data also allowed models for the north-south divide to be tested; again, see Figure 4. Both of these models were highly significant, confirming the north-south split in living standards

⁴⁴ Schwarz, "Trends in Real Wages," pp. 95–96.

⁴⁵ Hunt, *Regional Wage Variation in Britain*.

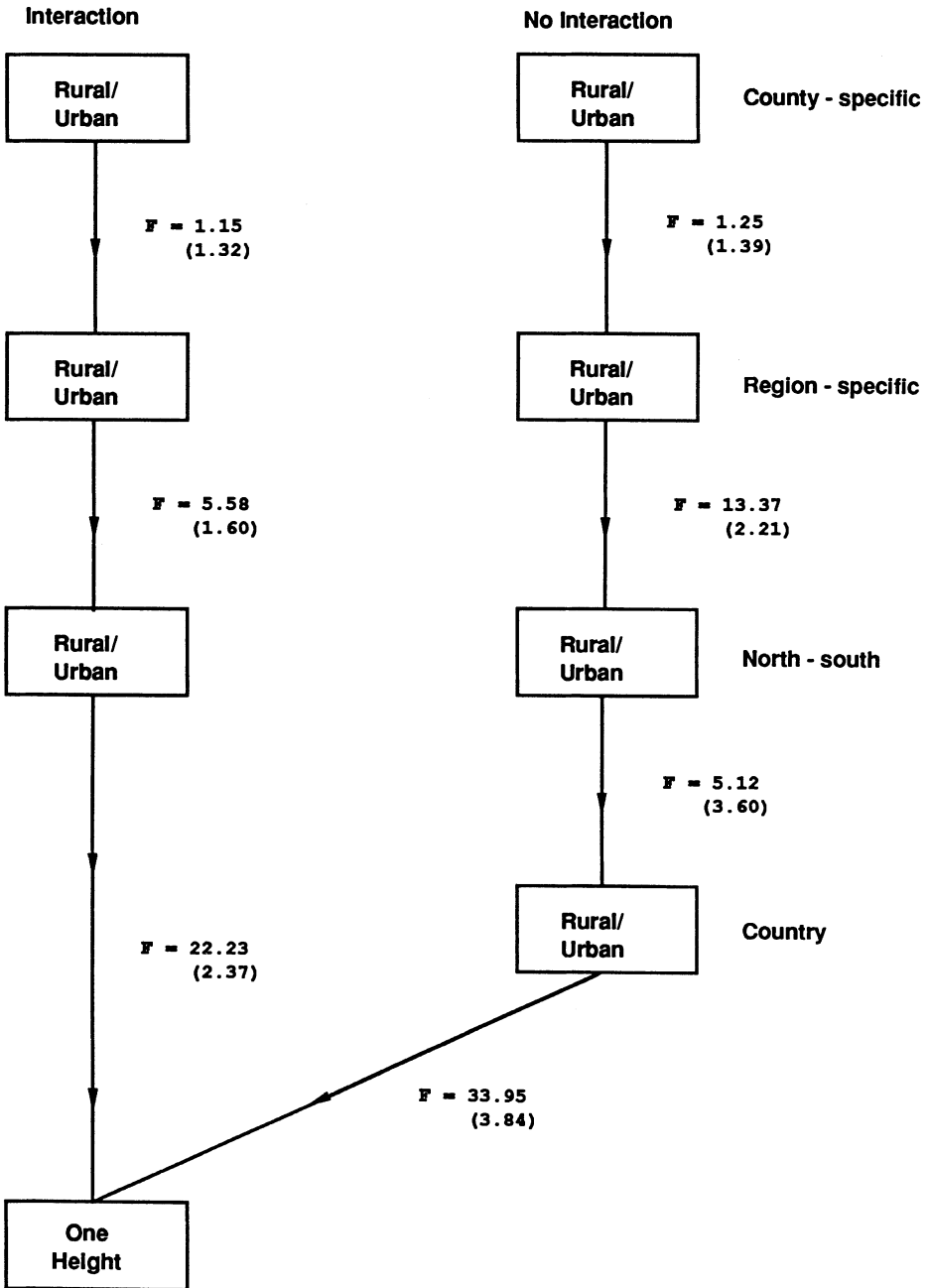


FIGURE 4
REGIONAL REGRESSION MODELS

Notes: the critical value of the $F_{0.5}$ -test is given in parentheses. For a breakdown of the regions, see Table 7. The number of observations was 5,064.

first popularized by Gilboy and more recently noted by Hunt and Botham. Though our data do not support any conclusions regarding changes in living standards between regions during the 1770-to-1815

TABLE 7
 TERMINAL HEIGHT FOR THE REGIONAL MODEL
 (in inches)

Region	Rural	Urban
London/home counties	65.68 (490)	64.80 (642)
South	65.92 (1,000)	65.91 (337)
Midlands	65.84 (713)	65.41 (439)
North	66.05 (670)	65.63 (456)
Fringe	66.59 (67)	66.20 (41)

Note: Sample sizes are given in parentheses.

period, our tests uncovered well-defined regional patterns in height, with the north and fringe showing better nutritional standards than the south and London.

CONCLUSION

Data on per capita income, consumption, and real wages are not robust enough to provide conclusive evidence on changes in living standards during the early years of British industrialization. The anthropometric investigation of human growth offers an alternative approach for assessing pre-1820 living standards. Because the English convicts transported to Australia before 1840 were broadly representative of the working class at home, data on their height can be used to measure changes in English living standards between 1770 and 1815. The height of both rural and urban workers fell significantly after 1780; rural Englishmen born in 1813 were almost 1 inch shorter than cohorts born in 1780, and urban Englishmen were over 1.5 inches shorter in 1802 than cohorts born in the late 1770s. The evidence shows that the growth spurt of English workers was delayed, that their growth continued much longer (at least until the age of 23), and that their final attained height fell from centile 20 in the 1770s to centile 6 for urban-born and centile 12 for rural-born Englishmen near the end of our period.

Using Ireland as a “control economy” relatively untouched by rapid industrialization, we discovered that English workers’ growth spurt was delayed by one year and that during their growing years Englishmen were shorter than Irishmen, a gap closed by rural-born but not by urban-born Englishmen at maturation. This evidence suggests that English workers experienced falling living standards during the early years of the British Industrial Revolution.

Food shortages caused by poor harvests and the Napoleonic wars explain much but not all of the decline in living standards before 1820. Although agricultural workers fared better than town workers during

times of food shortage, the different pattern and more pronounced decline in urban heights imply that the poorer work and living environment in English cities also accounted for the shorter stature of urban relative to rural Englishmen. Besides urban-rural differences in height, significant regional variations in living standards were uncovered: workers in London and the south were shorter than workers in the north and the fringe.

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