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ABSTRACT

This essay discusses recent progress that has been made in understanding the connection between health and industrialization in 8 developed countries. Because earlier efforts have been stymied by lack of reliable measures of mortality, the most recent work utilizes average height obtained from military records. Average heights measure a population's history of net nutrition during the growing years. Based on this measure, health improved uniformly during industrialization in Sweden, but it actually declined for several decades in two countries and generally improved with interruptions in others. Health was inversely correlated with the degree of urbanization across countries and rising urbanization led to health deterioration, especially in England, Australia, and Japan. Public health policy, diets, and business cycles were also important for health during industrialization.

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Generations of social observers, health policy workers, economists, historians, demographers, and other social scientists have pondered on the relationship between industrialization and health in the past. Because industrialization eventually led to generally higher incomes, one might suppose the answer to be straightforward: rising living standards associated with industrialization increased the chances that families consumed basic needs and acquired medical care that improved health. While this was true in the long-run, much discussion has focused on how various groups faired during the decades that industrialization actually unfolded. Scholars of the subject has asked who gained and who lost in the process (and why), and whether industrialization was accompanied by events that adversely affected health and human welfare. Debate persists because evidence about the past is often meager and, in any event, health and human welfare are complex and difficult to assess under the best circumstances of data availability.

This paper draws attention to recent progress in the field made by several scholars in comparative studies of 8 countries: the United Kingdom, the United States, the Netherlands, France, Sweden, Germany, Australia, and Japan (see Steckel and Floud 1997). This work focuses mainly on the nineteenth century, but the process in some countries, such as Japan, continued into the next century. While using traditional measures such as per capita Gross National Product and where available, life expectancy (or mortality rates), the authors also make extensive use of a newly forged data source: anthropometric measures, particularly human stature gathered from military records. The height data furnish important insights into nutritional status and health during childhood and adolescence.

On the supposition that some readers may be unfamiliar with the methodology of anthropometric history, the next section examines patterns of human growth and their relationship to more traditional measures of human well-being, including per capita GDP and life expectancy at birth. Following a brief discussion of the characteristics of industrialization, the paper examines the connection between health and industrial change in the past.

Methodology

There is a long tradition among human biologists and nutritionists of using stature to assess health aspects of human welfare (Tanner 1981). The realization that environmental conditions influenced growth stimulated interest in human growth studies in the 1820s. Auxological epidemiology (auxology is the study of human growth) arose in France, where Villermé studied the stature of soldiers; in Belgium, where Quetelet measured children and formulated mathematical representations of the human growth curve; and in England, where Edwin Chadwick inquired into the health of factory children. Charles Roberts judged the fitness of children for factory employment by using frequency distributions of stature and other measurements, such as weight-for height and chest circumference. Franz Boas identified salient relationships between the tempo of growth and height distributions, and in 1891 coordinated a national growth study, which he used to develop national standards for height and weight. The twentieth century has witnessed a worldwide explosion of growth studies (Eveleth and Tanner 1976, 1990).

These studies have shown that two periods of intense activity characterize the growth process following birth (Tanner 1978). Figure 1 shows that the increase in height, or velocity, is greatest during infancy, falls sharply, and then declines irregularly into the pre-adolescent years. During adolescence, velocity rises sharply to a peak that equals approximately one-half of the velocity during infancy, then declines rapidly and reaches zero at maturity. The adolescent growth spurt begins about two years earlier in girls than in boys and during their spurt girls temporarily overtake boys in average height. As adults, males are taller than females primarily because they have approximately two additional years of growth prior to adolescence.

The height of an individual reflects the interaction of genetic and environmental influences during the period of growth (Waterlow and Schürch 1994). According to Eveleth and Tanner (1976 p. 222):

> Such interaction may be complex. Two genotypes which produce the same adult height under optimal environmental circumstances may produce different heights under circumstances of privation. Thus two children who would be the same height in a well-off community may not only be smaller under poor economic conditions, but one may be significantly smaller than the other....If a particular environmental stimulus is lacking at a time when it is essential for the child (times known as "sensitive periods") then the child's development may be shunted as it were, from one line to another.

Although genes are important determinants of individual height, studies of genetically similar and dissimilar populations under various environmental conditions suggest that differences in average height across most populations are largely attributable to environmental factors. In a review of studies covering populations in Europe, New Guinea, and Mexico, Malcolm (1974) concludes that differences in average height between populations are almost entirely the product of the environment. Using data from well-nourished populations in several developed and developing countries, Martorell and Habicht (1986) report that children from Europe or European descent, Africa or African descent, and from India or the Middle East have similar growth profiles. Far-Eastern children or adults are an exception that may have a genetic basis. About two decades ago, well-off Japanese, for example, reached the fifteenth height percentile of the well-off in Britain (Tanner et al. 1982). But recent height gains in Japan suggest that the portion of the height differential that can be attributed to genetic influences is shrinking. Important for interpreting stature in the United States is the fact that Europeans and people of European descent, and Africans and people of African descent who grew under good nutritional circumstances have nearly identical stature (Eveleth and Tanner 1976, Appendix).[1]

Height at a particular age reflects an individual's history of <u>net</u> nutrition, or diet minus claims on the diet made by work (or physical activity) and disease. Metabolic requirements for basic functions such as breathing and blood circulation while at rest also make claims on the diet. The synergy between malnutrition and illness may further reduce the nutrition left over for growth (Scrimshaw, Taylor, and Gordon 1968). Poorly nourished children are more susceptible to infection, which reduces the body's absorption of nutrients. The interaction implies that analyses of stature must recognize not only inputs to health such as diet and medical care, but also work effort and related phenomena such as methods of labor organization. Similarly, researchers must attempt to understand ways that exposure to infectious disease may have placed claims on the diet.[2]

The sensitivity of growth to deprivation depends upon the age at which it occurs. For a given degree of deprivation, the adverse effects may be proportional to the velocity of growth under optimal conditions (Tanner 1966). Thus, young children and adolescents are particularly susceptible to environmental insults. The return of adequate nutrition following a relatively short period of deprivation may restore normal height through catch-up growth.[3] If conditions are inadequate for catch-up, individuals may still approach normal adult height by an extension of the growing period by as long as several years. Prolonged and severe deprivation results in stunting, or a reduction in adult size.

Figure 2 is a useful organizing device for exploring the relationship of height to living standards. Stature is a function of proximate determinants such as diet, disease and work intensity during the growing years, and as such it is a measure of the consumption of basic necessities that incorporates demands placed on one’s biological system. Because family income heavily influences purchases of basic necessities such as food and medical care, stature is ultimately a function of access to resources and environmental sanitation. It is noteworthy that stature may be diminished by consumption of products, such as alcohol or drugs that are harmful to health, but excessive consumption of food, while leading to rapid growth, may impair health in later life. Public health measures, personal hygiene, and the disease environment affect the incidence of disease that places claims on nutrition. In addition, human growth may have functional consequences for health, labor productivity, mental development, and personality, which in turn may influence socioeconomic conditions.

Comparisons with Other Measures

Because real GNP per capita is the most widely used indicator of living standards, it is particularly useful to compare and contrast this measure with stature (Steckel 1983, 1995; Floud 1994). Income is a potent determinant of stature that operates through diet, disease, and work intensity but one must recognize that other factors such as personal hygiene, public health measures, and the disease environment affect illness, while work intensity is a function of technology, culture, and methods of labor organization.[4] In addition, the relative price of food, cultural values such as the pattern of food distribution within the family, methods of preparation, and tastes and preferences for foods may also be relevant for net nutrition. Yet influential policy-makers view higher incomes for the poor as the most effective means of alleviating protein-energy malnutrition in developing countries (World Bank 1993, p. 75).[5] Extremely poor families may spend two-thirds or more of their income on food, but even a large share of their very low incomes purchases inadequate calories. Malnutrition associated with extreme poverty has a major impact on height, but at the other end of the income spectrum expenditures beyond those needed to satisfy calorie requirements purchase largely variety, palatability, and convenience.

Gains in stature associated with higher income are not limited to developing countries. Within industrialized countries, height rises with socio-economic class (Eveleth and Tanner 1990, p. 199). These differences in height are related to improvements in the diet, reductions in physical work loads, reduced exposure to pathogens (through sewage disposal, a cleaner water supply, and improved housing) and better health care. Expenditures on health services rise with income and there is a positive relationship between health services and health (Fuchs 1972).

At the individual level, extreme poverty results in malnutrition, retarded growth, and stunting. Higher incomes enable the parents of growing children to purchase a better diet and height increases correspondingly, but once income is sufficient to satisfy caloric requirements, individuals often consume foods that also satisfy many vitamin and mineral requirements. Height may continue to rise with income because a more complete diet or better housing and medical care are available. As income increases, consumption patterns change to realize a larger share of genetic potential, but environmental variables are powerless after individuals attain the maximum capacity for growth.[6] The limits to this process are clear from the fact that people who grew up in very wealthy families are not physical giants.

While the relationship between height and income is nonlinear at the individual level, the relationship at the aggregate level depends upon the distribution of income. Average height may differ for a given per capita income depending upon the fraction of people with insufficient income to purchase an adequate diet or to afford medical care. Because the gain in height at the individual level increases at a decreasing rate as a function of income, one would expect average height at the aggregate level to rise, for a given per capita income, with the degree of equality of the income distribution (assuming there are people who have not reached their genetic potential).

The empirical relationship between average height and per capita income has been studied by linking data from mid or late twentieth-century national height studies, found in Eveleth and Tanner (1976, 1990), with estimates of per capita Gross Domestic Product (in 1985 $) obtained in Summers and Heston (1991). The height studies were done on national populations in the mid and late-twentieth century. The scatter diagram in Figure 3 confirms the relationship between average height and per capita income discussed above.[7] The relationship is clearly nonlinear and is readily fit by a log function using regression analysis. The diagram depicts the heights of boys, but the equations below show that a similar pattern applies to girls (t-values in parentheses):

Boys aged 12: Height = 107.61 + 4.48 ln (GDP per capita), N = 18, R^2 = 0.70
(17.07) (6.18)

Girls aged 12: Height = 108.00 + 4.66 ln (GDP per capita), N = 17, R^2 = 0.68
(15.13) (5.65)

Scatter around the average relationship may be explained by variation across countries in the degree of income inequality, differences in public health policies, by food prices, and by cultural factors that affect the distribution of resources within families. These conditions affect the number and the degree to which basic needs are being met within the population. Despite the large number of factors that may influence average height at a given level of per capita income, however, the simple correlations between a country's average height and the log of its per capita GDP are in the range of 0.82 to 0.88 (Steckel 1983, 1995).[8]

A strong association between stature and per capita income also existed a century earlier. In a study of European countries in the late nineteenth and early twentieth centuries, Floud (1994) found a height-income relationship similar to that observed in more recent data. Although the height-income relationship has been less well-studied in eras before the late nineteenth century, the available evidence points to diverse outcomes, including a strong association in France, the Netherlands and in Japan, and a weak relationship in the United States. Certainly counterexamples (countries taller than their income alone would suggest) can be found, including Ireland in the early nineteenth century and America in the late

Colonial and early National periods (Mokyr and Ó Gráda 1988; Nicholas and Steckel 1992; Costa and Steckel 1997). It has also been noted that taller populations of the eighteenth and nineteenth centuries tended to live in rural, isolated, and less commercial regions (Komlos 1989; Sandberg and Steckel 1988; Shay 1986; Margo and Steckel 1983). Given that a nonlinear relationship exists between height and income, and that the height-income relationship could shift over time (due to changes in medical technology, for example), it can be concluded that heights and income measure different but related aspects of the standard of living.

Figure 4 shows the connection between average height and life expectancy at birth for the same countries as depicted in Figure 3. Unlike the height-per capita GDP relationship, which was clearly nonlinear, the pattern in Figure 4 is approximately linear, and the average tradeoff may be estimated using linear regression analysis (t-values in parentheses):

Boys aged 12: Height = 106.57 + 0.601 (Life Expectancy), N = 18, R^2 = 0.80
(21.53) (8.09)

Girls aged 12: Height = 110.99 + 0.521 (Life Expectancy), N = 17, R^2 = 0.84
(26.30) (8.87)

The slopes range from 0.52 to 0.60, depending upon gender, which implies that a one year increase in life expectancy is associated with an increase in stature of about 0.56 cm (average of the genders).

Unfortunately, empirical work on the association between life expectancy and average stature is thin for the nineteenth century, but there are good biological reasons for believing that a strong relationship existed. Human growth and health are opposite sides of the same coin because children are at greater risk of death if they grow poorly from bad diets, hard work or exposure to disease.

The connection between average height and life expectancy in a historical setting is most reliably calculated for the late industrial period, when better estimates of life expectancy are available. Because children's heights (and those of females) are generally unavailable for this time period, only adult males are available for study. Figure 5 shows the scatter diagram for the US, UK, the Netherlands, France, Sweden, Germany, Japan, and Australia. The estimated regression line is (t-values in parentheses):

$$\text{Height} = \underset{(18.03)}{152.48} + \underset{(1.98)}{0.330}\,(\text{Life Expectancy}),\ N = 8,\ R^2 = 0.40$$

The R^2 is substantially below that for the children aged 12 primarily because Japan is an outlier. If Japan is omitted, the R^2 rises to 0.79 and the regression coefficient is statistically significant at 0.01. Japan's stature is too low given its life expectancy, possibly because the time-frame of the observations do not agree. Conditions in the 1930s, when the young adults of mid-century were growing children, were conceivably much worse than those measured by life expectancy in 1950, a few years following the end of WWII. It is also possible that the height-life expectancy relationship is somewhat nonlinear at low levels of health.

Whatever the explanation (i.e. whether Japan is included or excluded), the slope of the relationship is lower in Figure 5 than in Figures 3 and 4. Among adult males of the late 19th and early 20th centuries, a year of life expectancy was worth only 0.33 centimeters of stature, as opposed to 0.56 centimeters among children aged 12. This might result from the vast gap in time periods being compared, during which medical knowledge and practice changed significantly, and this differentially affected growth and mortality. It is also likely that individuals measured as adults simply had more time during their growing years to recover from environmental insults (catch-up growth), which would lessen the slope of the relationship.

Urbanization and Health

Scholars do not know the extent to which human welfare during industrialization was governed by general tendencies and similar causal structures or by idiosyncratic factors and the cumulative influences of historical accidents that affected countries unequally—such as major wars or the acquisition of and settlement of new territories. Aligning the results for individual countries by stage of industrialization establishes a common framework for study, and suggests that some general tendencies prevailed.

Several decades ago, economic historians abandoned the idea that industrialization proceeded in a rigid sequence of events. They agree, however, that some order prevailed. England was clearly the first industrial country, and the process of industrialization spread across Europe from west to east. Significant industrial activity began in the United States sometime in the early nineteenth century, and economic growth accelerated in Australia near the middle of the century. The transformation did not begin in Japan until the 1880s.

Table 1 arrays countries by the timing of their most intense period of industrial change, when mechanization and factory methods of production penetrated numerous industries and spread geographically. It should be noted that some countries never developed large industrial sectors. Australia relied extensively on agriculture and mining, while the Netherlands (lacking coal and waterpower), developed banking, shipping, and services.

The table also shows average male height and per cent urban (towns or cities of 2,500 population or more) varied widely across the countries during the period of most intense change. With regard to stature, the extremes were established by the Australians (172 cm) and the Japanese who fell more than 13 cm behind. In urban development, the Swedes had the smallest share living in towns or cities (only 17.2 per cent) while the Japanese were the most urban (60 per cent).

It was not accidental that the Japanese were both the shortest and the most urban. In an era before widespread, effective investments in public health and personal hygiene, the congestion and turnover associated with urban living increased the chances of exposure to pathogens. Other features detrimental to health are often found in cities, such as a large number of poor people who lacked access to food, clothing and shelter that would have increased resistance to disease.

The scatter diagram in Figure 6 confirms the adverse effect of urbanization on health. The estimated regression equation is (t-values in parentheses):

$$\text{Height} = \underset{(40.69)}{174.07} - \underset{(-1.47)}{0.153}\,(\text{Per cent Urban}),\ N = 8,\ R^2 = 0.27$$

For every percentage point increase in the degree of urbanization, average male height fell by about 0.15 centimeters. This magnitude is significant in a practical sense because the transition from a low (say, 20 per cent) level of urbanization to a moderately high level (say 50 per cent) would have decreased average height by 4.5 centimeters. The notable outlier to the inverse relationship was Australia, which had the tallest population and the second highest level of urbanization. If

Australia is dropped from the regression, the t-value rises to –2.60, R^2 increases to 0.57, and the regression coefficient increases (in absolute value) by 50 per cent.

What factors explain the exceptional nature of health and urbanization in Australia? One was the relative geographic isolation of the country from major disease currents that affected cities in Europe and in North American. Another is the remoteness of the major cities within Australia from each other, which helped to reduce the spread of infectious disease. Moreover, Australia's industrialization (or modernization) occurred late enough to benefit from significant investments in public health. This last feature distinguishes Australia from Japan, which was also a late industrializer within this group.

Temporal Patterns

Additional factors that influenced health during industrialization can be discerned from study of temporal patterns within countries. The patterns can be placed into three categories of (a) important declines in health during a large phase of industrialization; (b) sustained, but not necessarily monotonic, improvement; and (c) a mixture that featured a series of short cycles.

Figures 7 and 8 show that the US and the UK fit the first pattern. Americans were very tall by global standards in the early nineteenth century as a result of their rich and varied diets, low population density, and relative equality of wealth. Between 1830 and roughly 1880, however, the average height of American men fell by about 3 centimeters, a reversal that was not offset until the 1920s. Consistent with this height decline, life expectancies tabulated from genealogies also show a deterioration near the middle of the century (Pope 1992). Researchers in the field have suggested numerous possible causal factors for the decline, including the spread of disease affiliated with the development of railroads, canals, and steamboats (for discussions see Steckel, 1995 and Komlos

(1998). Also mentioned are higher food prices; growing inequality, the emergence of business cycles that led to malnutrition during contractions, urbanization, and the rise of public schools that exposed children to major diseases. Unfortunately, research has not advanced to the point of assigning plausible weights to these factors.

Although health deterioration also occurred in Britain during the early-mid nineteenth century, the timing is probably more coincidental than emblematic of similar causal factors at work. While it is possible that growing trade and commerce spread disease, as in the United States, it is more likely that a major culprit was rapid urbanization and associated increased in exposure to diseases. This conclusion is reached by noting that urban born men were substantially shorter than the rural born, and between the periods of 1800-1830 and 1830–1870 the share of the British population living in urban areas leaped from 38.7 to 54.1 per cent.

The UK is the only country to date for which a large data base has been assembled for women in the eighteenth and nineteenth centuries, in this case from convict and prison records. Comparisons with heights of men from the same sources provide insights into resource allocation within the family, a phenomenon difficult to study from traditional sources such as wages or income. Johnson and Nicholas (1997) report that the gap between male and female heights widened during the late eighteenth and early nineteenth centuries but were substantially correlated after 1815, including the period of height decline after 1830. The relative height decline of women in the earlier period may have resulted from declining labor market opportunities for women, which led to a deterioration in diet and possibly harder work for young women.

Sweden realized the most sustained increase in health during the most intense period of industrialization (late nineteenth century), but France, the

Netherlands, and Japan also posted significant, if somewhat interrupted, gains. Figure 9 shows that average adult male heights in Sweden rose from 168 to 172.5 centimeters between 1860 and 1900. The only downturn was the small reversal that occurred during the crop failures of the late 1860s, which had little to do with industrialization (Sandberg and Steckel 1997). Paralleling the growth in stature were declines in childhood mortality rates of roughly 50 per cent. It is notable that Sweden had the least urbanized population among the 8 countries studied, and it also benefited from a high literacy rate, public health measures such as vaccination, and from relatively low food prices created by the spread of potato cultivation and imports of food from America.

Most noticeable in the Dutch experience (Figure 10) was the large pre-industrial height decline that was caused in part by rising food prices and stagnating nominal wages (i.e. a decline in purchasing power). This trend was not reversed until the conscription years of the late 1850s (birth years of the late 1830s). Thereafter, average heights increased more or less continuously into the twentieth century with the exception of the reversal and stagnation of those measured from the late 1880s through the late 1890s. The latter was associated with the income decline of the 1860s and the economic depression of the 1870s (Drukker and Tassenaar 1997).

The French experience (Figure 11) of the late nineteenth century is similar to that of the Netherlands. On the eve of industrialization, both populations attained about 164 centimeters and both realized slow and steady growth in heights with the exception of the slight reversal and stagnation for those measured in the last decade of the century. The steady advance in heights was accompanied by steady progress in economic measures such as GDP per capita and by life expectancy. Like the Netherlands, France also experienced a decline in economic conditions that affected average heights; a downturn in real wages in the early 1860s was followed by a decade and a half of stagnation (Weir 1997).

Figure 12 shows that Japan opened the industrial era at the turn of the twentieth century with the smallest stature (about 157 centimeters) of any industrializing country. Hampered by a low protein diet, thereafter progress was slow and significantly correlated with per capita GDP but adversely affected by economic policy that diverted resources to the military (Honda 1997). Its high level of urbanization and modest investments in public health were obstacles to human growth. Economic stagnation in the 1920s and the depression of the 1930s (which was rather mild in Japan) brought the modest gains in height to a halt in the mid 1930s.

Germany and Australia realized gains in health during industrialization, but progress was choppy, or otherwise interrupted by relatively brief cycles in height (Twarog 1997). Figure 13 shows the stature advantage of rural over urban residents that characterized all countries studied in this era. Adult males reached about 163.5 centimeters (average of rural and urban) in the province of Württemberg on the eve of industrialization, which began in the 1860s. A small spurt in average heights occurred during the 1870s, followed by decline and stagnation in the 1880s. This temporal pattern was related to the financial crash of 1873 and the subsequent depression that lasted into the early 1890s. Occupational differences in stature indicate that the professional classes were protected during the early phases of the economic depression and the loss in health was concentrated among the middle and lower classes. Thus, growing inequality played an important role in Germany's health trends during industrialization.

Figure 14 shows two features distinguish the Australian experience: the tall stature (about 172.5 centimeters) on the eve of modernization that was followed by a large cycle in heights whereby the average height of the mid 1870s was not attained again until the second decade of the twentieth century (Whitwell, de Souza and Nicholas 1997). The tall stature is undoubtedly related to an inexpensive diverse diet that was also rich in protein, a phenomenon giving rise to the view that Australia was a workingman's paradise. Even though the share living in urban areas was relatively high (about 50 per cent), overall population density was low and the country and its major cities were relatively isolated.

But some troubles occurred even in these relatively idyllic circumstances. The height downturn of the 1880s and 1980s was the result of a double whammy. The share living in urban areas was already high (43 per cent in 1881) and then jumped 8 percentage points in the decade following. A sanitary crisis followed and typhoid fever, which disproportionately affected the young, was epidemic in the cities. Although the pace of urbanization fell considerably during the 1890s, GDP declined and remained relatively low for a decade, thereby dampening any hopes for quick recovery in heights and health.

Conclusions

Study of height and mortality patterns in counties diverse by time period of industrialization and by environmental factors indicates that a combination of general tendencies and idiosyncratic factors affected health during the industrial revolutions of the nineteenth and early twentieth centuries. In an era when public health policies were often lacking or meagerly enlightened by theories of disease causation, urbanization was a widespread culprit in ill health within countries studied in Europe and in the Pacific, and within the US. Height was inversely correlated with degree of urbanization across countries, and rising urbanization led to health deterioration, especially in England, Australia, and Japan.

Major business cycles also affected heights and health. France, the Netherlands, Germany, and Australia were victims of major downturns. Changing economic opportunities, in the form of growing inequality, adversely affected heights in Germany and the US.

Diets were important for health and human growth. Countries with the tallest men (Australia and the US) had excellent access to a variety of foods, some of which were rich in protein. Food was expensive and the diet was low in protein in the country with the smallest stature (Japan).

Lastly, public health policy (or lack thereof) was also important for health. Countries that industrialized early, such as the US and the UK suffered the most, in part because the adverse effects of trade and population concentrations on health could not be offset by health policies informed by reliable theories of disease causation. Merely arriving late on the scene was no guarantee of protection against the byproducts of industrialization, however, as shown by the Japanese case where resources that could have been used for public health and human growth were diverted to the military.

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Table 1: Height and Per Cent Urban at Mid-Phase of Industrialization

Country	Middle Industrial Period	Average Male Height	% Urban
United Kingdom	1800-1830	170.7	38.7
United States	1850-1880	170.6	22.3
France	1850-1880	165.4	31.0
the Netherlands	1870-1900	168.6	46.0
Sweden	1870-1900	171.4	17.2
Germany	1870-1900	167.5	43.6
Australia	1890-1920	172.0	53.0
Japan	1900-1920	158.8	60.0

Source: Steckel and Floud (1997, Table 11.1).

Footnotes

[1]To compare health status in situations where genetic differences are relevant, stature can be converted into percentiles of the appropriate (ethnic, regional or country-specific) height standards.

[2]An alternative view of stature is the “small but healthy” paradigm emphasized by Sukhatme (1982), Seckler (1982) and others, in which it is claimed that many individuals adapt with low costs to nutritional deprivation. For critiques of this view see James (1987), Martorell (1989), Dasgupta (1993).

[3]Ingestion of toxic substances, such as alcohol or tobacco, in utero or in early childhood may create permanent stunting regardless of subsequent nutritional conditions.

[4] Empirical models of the relationship between a country’s per capita GNP and average height are discussed below. More elaborate models would consider a lagged relationship between income and stature, both at the household and the aggregate (national) level. For example, adult stature is a function of average income in each year from conception to maturity and growth is more sensitive to income levels at ages when growth is ordinarily high, i.e. during early childhood and adolescence. For an application of this idea see Brinkman, Drukker and Slot (1988).

[5]Development economists have debated the effects of income on the diets of the poor. See Behrman and Deolalikar (1987).

[6]Of course, it is possible that higher incomes could purchase products such as alcohol, tobacco, or drugs that impair health.

[7] The countries are Czechoslovakia, West Germany, the Netherlands, New Zealand, USA, Japan, South Korea, Egypt, India, Belgium, Denmark, Hungary, Italy, Argentina, and Australia. Three countries have two height studies conducted at different dates.

[8] The log specification fits about as well as a quadratic or cubic polynomial, and given these results the log is preferred on grounds of simplicity.