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How have Europeans grown so tall?

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Increases in human stature are a key indicator of improvements in the average health of populations. In this article I present and analyse a new data set for the average height of adult male birth cohorts, from the mid-nineteenth century to 1980, in 15 European countries. In little more than a century average height increased by 11 cm—representing a dramatic improvement in health. Interestingly, there was some acceleration in the period spanning the two world wars and the Great Depression. The evidence suggests that the most important proximate source of increasing height was the improving disease environment as reflected by the fall in infant mortality. Rising income and education and falling family size had more modest effects. Improvements in health care are hard to identify, and the effects of welfare state spending seem to have been small.

JEL classifications: I12, I38, N24.

1. Introduction

One of the most important gains to human welfare in the past century has been the improvement in health status. The average stature of human populations is a key indicator of health conditions, particularly during childhood. On this measure the long-run trends are striking. In a little more than a century, the average height of young adult European males has increased by about 11 cm. Although average height has fluctuated across the centuries, the increase since the late nineteenth century has been truly unprecedented. This article asks how that happened. What were the socioeconomic underpinnings to such explosive growth? Through what mechanisms did they operate? Did public policy play a role?

The past decade has seen a growing interest among economists in exploring the links between socioeconomic conditions and health status indicators, such as height. Height is influenced by childhood circumstances and is associated with later life outcomes, such as educational achievement, cognitive ability, morbidity, and mortality. The burgeoning literature in epidemiology and health economics has focussed on the socioeconomic correlates of growth during childhood using surveys from the 1960s onwards (Silventoinen, 2003; Case and Paxson 2010). Meanwhile, economic historians have extensively documented and analysed trends in height during the eighteenth and nineteenth centuries (see Steckel, 1995, 2009). Although this literature has produced a variety of important insights, the rapid improvement in health during the first half of the twentieth century has received less attention than it deserves. Although the gap between these literatures is narrowing, we still lack a long-run analysis that spans the whole period from the middle of the nineteenth century to the late twentieth century.

The article first sets out to document the dramatic increase in height using a new data set of average adult male height for 15 countries, stretching back, where possible, to cohorts born in the 1860s and 1870s. These data show that cohort heights have increased fairly consistently up to the cohort born in 1976–80. A little more surprising is the fact that except for southern Europe, the gains in height were particularly strong in the period around the two world wars and the Great Depression. There follows a review of the literature that focusses on the epidemiological channels of influence and their links to measurable socioeconomic variables that could have increased average height over more than a century. Using these insights as a guide, I estimate fixed effects regressions to account for within-country changes in height. The results support existing findings that stress the effects of income per capita, family size, and education. The most important single influence is the improvement in the disease environment as proxied by the decline in infant mortality. This has a nonlinear effect and accounts for much of the spurt in height after 1911. Some of this upwards shift is associated with the growth of the welfare state and changes in the urban environment, but much of it remains unexplained. I conclude that a large part of the improvement in health and stature has been due to advances in knowledge of the effects of nutrition and hygiene and in medical practice—improvements that are hard to capture at the aggregate level.

2. Trends in the heights of Europeans

To track average heights over a long period, we have put together data from a variety of sources. The database of average adult heights (at the age of about 21) for 5-year birth cohorts used here covers 15 European countries, where possible going back to the middle of the nineteenth century. It builds on the work of many others; the sources and methods of construction are reported in detail in Hatton and Bray (2010). The underlying data are of two types. For the most recent decades we rely mainly on height by age from cross-sectional surveys. We build on the series for 1951–55 to 1976–80 provided for 10 countries by Garcia and Quintana-Domeque (2007), adding 5 more countries. In some cases we carry these back using earlier surveys for height by age. For the most part, observations for the earlier years are based on data for the heights of military conscripts or recruits, most of which have been published by economic historians. These series, presented as five-year birth cohorts, are for men only as the historical evidence on women's heights is severely limited.

The data are plotted by birth cohort in Fig. 1. Between the birth cohorts of 1871–75 and 1976–80, average male height in these countries increased by 11 cm, or about 1 cm a decade. This unprecedented increase in height is consistent with

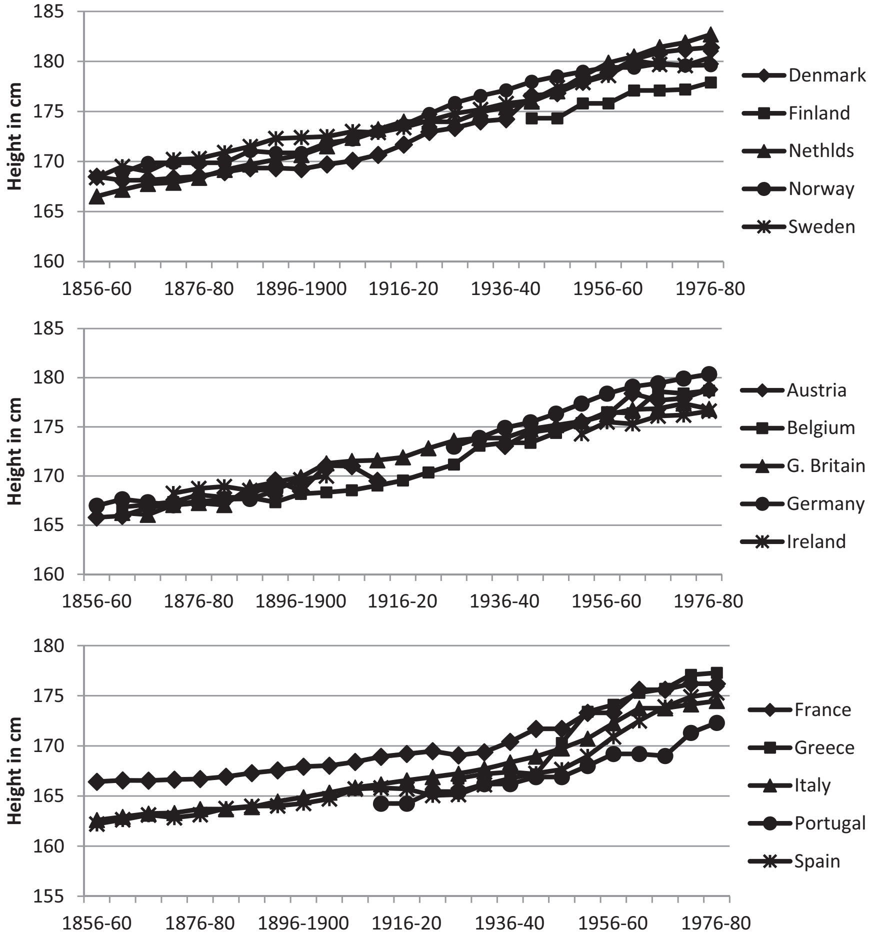

Fig. 1 Adult male height by birth cohort, 1856–60 to 1976–80.

results independently derived by Baten and Blum (2012, p. S75).[1] They also show that over this period European heights outpaced those typical of Africa, Latin America, and South Asia (Stegl and Baten, 2009; Baten and Blum, 2012). There is also some evidence of a distinct acceleration in growth in the middle of the data period. This can be see more clearly in Table 1, which presents the increase in average height per decade over the whole period from 1871–75 to 1976–80 and for three major economic eras: 1871–75 to 1911–15 (prewar), 1911–15 to 1951–55 (transwar), and 1951–55 to 1976–80 (postwar). Apart from Great Britain, the increase was slower in the prewar period than over the period as a whole. It is

[1] Longer-run data reveal no precedent. In their study of height in Europe over two millennia, Koepke and Baten (2005) find the maximum change (up or down) between any two adjacent centuries is about 2 cm (see also Steckel 2004).

Table 1 Increase in adult height of birth cohorts in centimetres per decade

	1871–75 to 1976–80	1871–75 to 1911–15	1911–15 to 1951–55	1951–55 to 1976–80
Austria	1.11	0.59	1.50	1.32
Belgium	1.08	0.41	1.59	1.32
Denmark	1.24	0.58	1.83	1.37
Finland				0.84
France	0.91	0.57	1.10	1.16
Germany	1.25			1.20
Great Britain	0.93	1.14	0.99	0.50
Greece				1.55
Ireland	0.80			1.00
Italy	1.06	0.72	1.14	1.50
Netherlands	1.41	1.34	1.32	1.67
Norway	0.93	0.79	1.49	0.26
Portugal			0.94	1.72
Spain	1.19	0.74	0.79	2.53
Sweden	0.97	0.68	1.25	1.00
Average	1.08	0.76	1.27	1.26
Std Dev	0.18	0.28	0.31	0.54

Source: Hatton and Bray (2010), Table 1.

notable that for Northern and Western Europe, except for the Netherlands, growth was slower after 1950 than in it was during the transwar period. By contrast, southern Europeans, who were considerably shorter at the outset, experienced their greatest increase in the postwar period. As a result there was some divergence followed by convergence in the variation across countries. The cross-country standard deviation increased by 0.3 between 1871–75 and 1911–15 (10 countries) and by 0.8 between 1911–15 and 1951–55 (11 countries) and then fell by 0.6 between 1951–55 and 1976–80 (15 countries).

The trends for different periods can be summarized using all the observations by regressing height on a time trend. Here the countries are grouped into three regions: North (Denmark, Finland, the Netherlands, Norway, Sweden), Middle (Austria, Belgium, Germany, Great Britain, Ireland), and South (France, Italy, Greece, Portugal, Spain). Table 2 presents coefficients from regressions of height on a time trend. The time trend increases in increments of 0.5 for every five-year period, so the coefficient can be read as centimetres per decade. Although the grouping of countries is somewhat arbitrary, the results confirm those observed in Table 1. In the North group the trend increases sharply in the transwar period and then returns to a more modest figure. For the Middle group the pattern is similar but not quite so pronounced. Rapid growth in the transwar period is all the more striking because this period embraces the two world wars and the Great Depression, and it predates the golden age of postwar growth, the introduction of new medical treatments, and the advent of universal health care systems. By contrast, the South countries show a quickening in the pace of growth across the

Table 2 Coefficient of time trend on adult height (cm per decade)

	1871–75 to 1976–80	1871–75 to 1911–15	1911–15 to 1951–55	1951–55 to 1976–80
	North (Denmark, Finland, the Netherlands, Norway, Sweden)			
Coefficient	1.24	0.84	1.43	0.99
t-value	41.8	13.5	22.5	8.1
Observations	96	36	39	30
Countries	5	4	5	5
	Middle (Austria, Belgium, Germany, Great Britain, Ireland)			
Coefficient	1.13	0.80	1.36	1.02
t-value	32.3	8.1	16.6	9.0
Observations	91	39	30	30
Countries	5	5	5	5
	South (France, Italy, Greece, Portugal, Spain)			
Coefficient	1.12	0.68	1.05	1.70
t-value	22.9	20.8	9.9	11.5
Observations	91	28	42	30
Countries	5	4	5	5

three periods, which is a little more consistent with the timing of their socioeconomic development. The question that naturally stems from these observations is what can account for this pattern of growth.

3. Socioeconomic determinants of health and height

What factors lie behind the dramatic increases in adult height that we have witnessed over the past century? Why has the twentieth century differed so much from earlier centuries? Clearly, we can rule out genetic evolution. Although genetic inheritance explains most of the differences between individuals,[2] evolution of the aggregate gene pool cannot account for substantial increases in mean stature over four or five generations. If anything, one would expect that Darwinian selection would have been less important in the twentieth century than previously. Note that here we are concerned with health principally in the first 20 years of life. In fact, much of the increase in height can be accounted for by the first two years of life (Cole, 2003), although growth might be slowed by adverse conditions somewhat later in childhood.[3]

[2] According to a Finnish study, genetic factors account for about 80% of the variance in height across individuals (Silventoinen *et al.*, 2000). See also McEvoy and Visscher (2009) for a survey of genetic influences on height.

[3] It is possible that the height attained in infancy might be affected by conditions *in utero*. In that case, the health of mothers might be important, as the fetal origins hypothesis suggests (Barker, 1995). But there seems to have been very little upwards trend in birth weights in the century to about 1980 (Rosenberg, 1988; Costa, 1998; Steckel, 1998) and thus secular increases in height must be largely due to postnatal influences (Hauspie *et al.*, 1996; Cole, 2000).

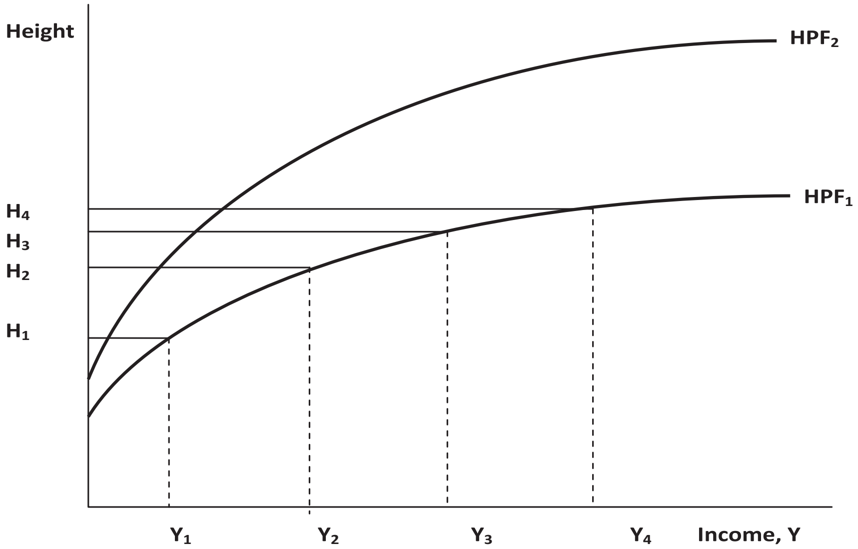

Fig. 2 The health production function.

As most of the literature attests, the two key influences on height are food and disease. These 'inputs' interact to produce net nutrition, and they have their major effects during early childhood. Although we cannot measure nutritional intake and the disease environment very directly, we can examine the socioeconomic trends that underpin these two key channels of influence on height. I focus on a number of key influences that have been highlighted in the literature. These cannot easily be partitioned into those uniquely associated with food and those associated with disease. Rather, they should be thought of as summarizing some of the background conditions that indirectly determine height through the two main channels.

3.1 Food and income

Much of the historical literature has focussed on the relationship between height and income or earnings. Income per capita is generally read as shorthand for food consumption, although the two variables have not always moved in lockstep. Nevertheless, as late as the turn of the twentieth century, working class families in the UK were spending 60% of their incomes on food, and so income must have been the principal constraint on the amount of food that the bulk of the population could consume. However, as critical nutritional thresholds are crossed, we should expect the marginal effect of an increase in income to decline as in Fig. 2. This concave health production function is widely acknowledged in the literature (Preston, 1975; Steckel, 1995, p. 1914; Easterlin, 1999, p. 259). It is also consistent with the widely observed decline in the share of household budgets spent on food.

Although income grew faster, on average, in the twentieth century than in the nineteenth century, the health production function suggests that its effects would become weaker. According to Maddison's data, the gross domestic product (GDP) per capita of Western Europe grew at annual rates of 1.3% from 1870 to 1913, 0.9% from 1913 to 1951, and 3.5% from 1951 to 1980. Strong economic growth after 1950 could be consistent with somewhat smaller increments to height if most countries had reached a relatively flat part of the health production function. This is illustrated by the increase from H_3 to H_4 in Fig. 2 as compared with the increase from H_2 to H_3. But it is more difficult to explain why heights increased so strongly in the transwar period as compared with the 40 years before World War I. According to Fig. 2, $H_2 - H_1$ should be larger than $H_3 - H_2$. Thus one of the puzzles that emerges from the long-run trends in height is why the apparent improvement in health was so strong in the transwar period.

One implication of a concave health production function is that mean outcomes will depend on both average income and its distribution. As several observers have pointed out, a decline in inequality should improve average health for a given average income (Steckel 1995), and more so the closer average income is to a minimum subsistence standard. As inequality has declined in Europe, especially over the first half of the twentieth century, this might account for somewhat stronger increase in height than average income alone would suggest.

Recent studies have shown that proximity to sources of basic foods such as grain, vegetables, milk and butter, and meat products had significant effects on height, and this explains much of the height advantage of rural communities (Baten and Murray, 2000; Baten; 2009). Urbanization increased the distance between consumers and sources of supply but transport improvements, especially the railways from the late nineteenth century, and improvements in the storage and processing of highly perishable protein sources (such as fresh milk) progressively improved the supply to the cities. It is notable that that the relative price of food fell during the transwar period, which would favour poorer urban households, although that trend may have been muted by substitution towards poor quality, less nourishing foods.[4]

Because the focus is on conditions during childhood, family structure matters, too. If there is a trade-off between the quality (as measured by health) and the quantity of children, then a decrease in family size could lead to an increase in height. For French départements, Weir (1993) found an inverse relationship between the height of young adults and lagged fertility rates over the whole of the nineteenth century. More recently, a study of household data for Britain in the 1930s finds that sibship size reduced average height both by diluting family income (and food consumption) per capita and directly through overcrowding. Through these two channels, falling family size accounted for two-fifths of the increase in children's heights between 1906 and 1938 (Hatton and Martin, 2010).

[4] Where price regulation led to shortages, as in Germany during the 1930s, the effects on health could be strongly negative (Baten and Wagner, 2003).

For the countries studied here, the downward trend in fertility was particularly strong between the 1900s and the 1930s, and so this may have contributed to the notable acceleration in height in the early twentieth century.

3.2 The disease environment

Some observers have argued that most of the health improvement since the late nineteenth century is due to an upwards shift in the health production function (Easterlin, 1999; Cutler *et al.*, 2006). These improvements in the health environment are seen most clearly in the steep declines in mortality rates across Europe (Millward and Baten, 2010, pp. 235–37). Although improvements in living standards are of some help, most of the increase in life expectancy is due to improvements in the disease environment. This is illustrated in Fig. 2 by the upwards shift from HPF_1 to HPF_2. Furthermore, if the health production function is relatively flat, then the movement along it would have contributed relatively little to these gains.

Epidemiological studies of the links between height and diseases point to the importance of repeated respiratory and gastrointestinal infections (Tanner, 1962; Rona and Florey, 1980). These infections, which are common to infants and young children, restrict the body's ability to absorb nutrients and may also limit growth through other mechanisms. Beard and Blaser (2004) stress the effects on growth of microbial infection, giving the example of the bacterium *Helicobacter pylori*, which colonizes the stomach and duodenum and is associated with crowded environments and contaminated water. Chronic infection triggers immune responses that are metabolically demanding and also elevate cortisol levels that can reduce growth by impairing protein synthesis (Crimmins and Finch, 2005, p. 500–501). Studies of UK birth cohorts have found that serious illnesses during childhood can reduce adult height by as much as 1–2 cm (Kuh and Wadsworth, 1989; Power and Manor, 1995).

The most sensitive indicator of the disease environment is infant mortality. In the nineteenth century and beyond, infants routinely died from variety of causes but particularly from diarrheal and respiratory diseases. Across Europe, infant mortality fell particularly steeply after the turn of the twentieth century. This dramatic decline in infant mortality is illustrated for the countries in our dataset in Fig. 3. Infant mortality rates fell from an average of 178 per thousand in 1871–75 to 120 per thousand in 1911–15 and then plummeted to 41 in 1951–55 and 14 in 1976–80. To the extent that infant mortality captures the underlying factors that determine the disease environment, this could have contributed to the upwards trend in height.

Several studies have found that infant mortality is linked to subsequent height. Bozzoli *et al.* (2009) examine country-level data on average heights of adults born between 1950 and 1980 (a subset of the data used here). Using postneonatal mortality in the cohort's birth year as a proxy for the disease environment, they find a negative effect that accounts for most of the increase in height over the

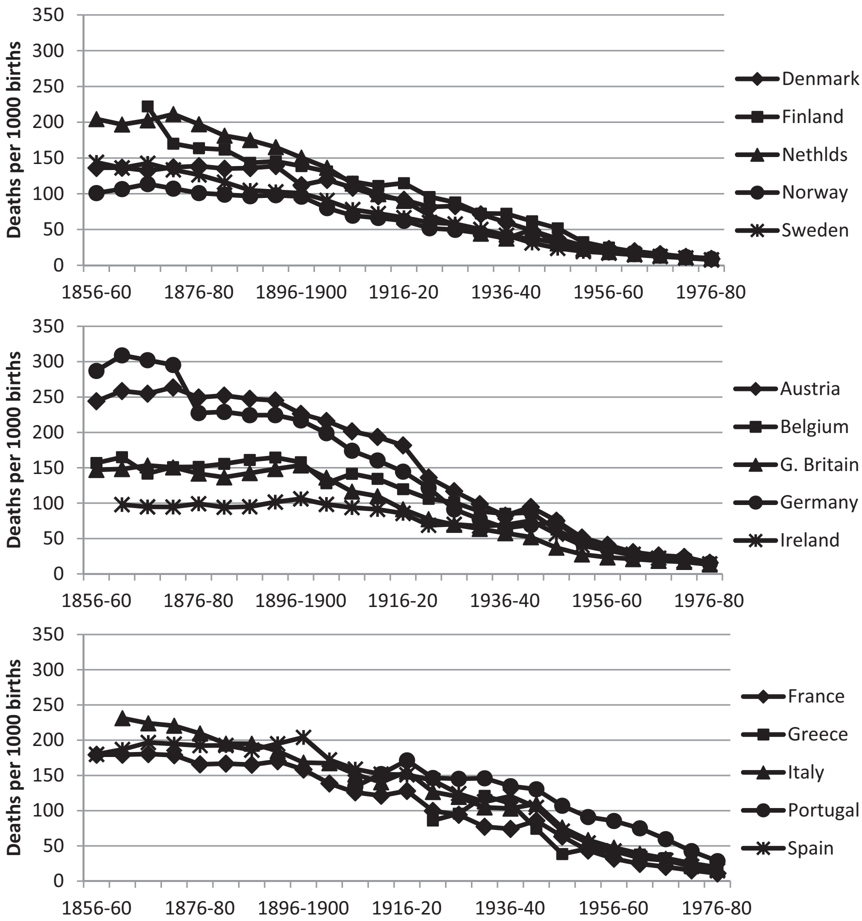

Fig. 3 Infant mortality rates, 1856–60 to 1976–80.

period. This is consistent with the results reported by Schmidt *et al.* (1995) and for earlier periods by Crimmins and Finch (2005), who use infant mortality as a proxy for the probability of infection. It is further supported in recent studies of the effects of declining infant mortality on the heights of school-age children in Britain, of adults in Spain, and of army recruits in Italy (Hatton, 2011; Peracchi and Arcaleni, 2011; Spijker *et al.*, 2012).

In the mid-nineteenth century cities were places of grime and squalor, the more so the larger and the more industrial the city. But from the end of the nineteenth century the retreat of horses from streets, and pigs and chickens from backyards, gradually removed some of the disease vectors from the urban environment. The decline in industrial pollution, the improvement in the supply to the cities of fresh foods (particularly milk) and the declining adulteration of processed foods all helped reduce the risk of disease and death. But perhaps the most important improvements were in sanitary conditions and housing (Millward and Baten, 2010, p. 240–41; Floud *et al.*, 2011, pp. 269–78, 326–27). Several studies have found that sanitary reforms had substantial effects on death rates, particularly on infant mortality (Bell and Millward, 1998; Cutler and Miller, 2005). From the late nineteenth century housing conditions improved as tenements and back-to-back slums were gradually replaced with better quality housing and as the process of suburbanization gathered pace. A study of Edinburgh and Glasgow found that the effects of overcrowding on infant mortality weakened over the twentieth century (Cage and Foster, 2002), possibly due to improvements in housing quality.

Whereas nineteenth century rural–urban mortality differences were large, the rural height advantage was more modest, typically amounting to 1 cm or less (Floud *et al.* 1990, p. 200–206; Alter *et al.*, 2004). In some countries they were negative (Twarog, 1997, p. 302; Martínez-Carrión and Moreno-Lázario, 2007). One reason is that the negative effect of the urban disease environment was partially offset by greater food intake as a result of higher real incomes in urban areas. In the nineteenth century the overall negative effect on height typically increased with city size and especially with population density (Foster *et al.*, 1983; Humphries and Leunig, 2009). But what urban penalty there was diminished over time as cities have become less infested, and they have typically become better health environments than more remote rural areas due to higher living standards and better access to fresh produce and medical services.

3.3 Medical knowledge and health services

What about medical advances and public health programmes? McKeown (1976, 1979) famously argued that, because most of the landmark medical discoveries of the twentieth century did not become available until around World War II, they cannot have contributed much to the improved health and declining mortality that occurred up to that time. Even when new treatments and improved medical expertise became available there was limited access to them.[5] Perhaps more important was the expansion of health services through public health programmes and the professionalization of medical practitioners (Millward and Baten, 2010, p. 241–42). Government-sponsored health insurance programmes, providing access to medical services, were introduced in the 1880s in Germany and Austria, followed by Belgium, Denmark, France, and Sweden in the 1890s, and Britain and Ireland in 1911. These early schemes were typically restricted to working-age breadwinners in certain occupations, with limited coverage of other

[5] Streptomycin (effective against tuberculosis) was introduced in 1947, sulphonamides and sulphapyridine (effective against bronchitis, pneumonia and influenza, and whooping cough) not before 1938, and antibiotics still later. Similarly, treatments for other childhood diseases such as measles and scarlet fever were developed in the 1930s, long after the steep decline in these diseases. Only the timing of the reduction in diphtheria mortality from around the turn of the century seems to be consistent with the advent of treatment by antitoxin. Examining causes of death in the Netherlands, Mackenbach (1996, p. 1210) estimates that improvements in medical care from the 1930s contributed between 4.7% and 18.5% to the total decline in mortality in the century up to 1970.

family members. Although they may have improved the health outcomes of adults,[6] the effects on children were probably negligible until the advent of national health systems after World War II. For most infants and children, access to health care was through maternity services, local clinics, and school medical services.

Perhaps the most important aspect of the health environment for young children was care in the home. Mokyr (2000) argues that improved knowledge of nutrition and the channels through which disease is transmitted led mothers to devote more time to child nurturing and housework than they otherwise would have. Other specific improvements identified in the literature include better knowledge of hygiene and feeding methods as well as improved understanding of the aetiology of common illnesses and methods of protection against pathogens. These developments are notoriously hard to measure, but one might expect improved nurturing to be correlated with the increase in parental education as well as with the decline in family size. One question is whether growth in education and health awareness and the development of health-related social services were complements in health production or whether they were substitutes. This question is examined further next.

4. Empirical results

Several previous studies have examined country-level panel data on heights, usually with a relatively small set of explanatory variables and on data up to around the 1920s. Floud (1994) and Steckel (1995) found a positive effect of per capita income and a negative effect of infant mortality. Using a similar database, Schneider (1996) found evidence that height was also negatively related to the marital fertility rate. Examining data for birth cohorts from 1940 to 1980 Peracchi (2008) finds evidence of a positive effect for both income and education. For the postwar period, Bozzoli *et al.* (2009) found strong negative effects for postneonatal mortality but no effect for income. This contrasts with results for the earlier era, in which both income and infant mortality seem to matter. These studies typically focus on very few variables, and none of them covers the whole period since the late nineteenth century.

A few studies have modelled long-run annual data for a single country. María-Dolores and Martínez-Carrión (2011) studied height in Spain from 1850 to 1958. They found that, in addition to infant mortality, height depended on consumption of hygiene products, on the relative price of consumption goods and on economic openness. Quintana-Domeque *et al.* (2011) identify effects of disease in Spanish provinces for postwar cohorts but find no income effect. Jacobs and Tassenaar (2004) examined the deviations from trend in height in the second half of the nineteenth century in the Netherlands. They found that real wages were more important than GDP per capita and that the timing of the effects on each cohort coincided with growth spurts, particularly at the stage of infancy.

[6] Winegarden and Murray (1998, 2004) find a negative effect of health insurance coverage on aggregate death rates for five countries in the period 1875–1913.

4.1 Proximate determinants of height

I use the unbalanced panel of adult male heights introduced earlier to examine the contributions of some of the variables. Details, mentioned above of the data sources and definitions, are provided in the Appendix. The model to be estimated is:

$$H_{it} = \alpha_1 Y_{it-4} + \alpha_2 G_{it-4} + \alpha_3 F_{it-4} + \alpha_4 E_{it-4} + \alpha_5 M_{it-4} + \mu_i + \varepsilon_{it},$$

where H is height, G is a measure of inequality, F is family size, E is education years for the parent's generation, and M is infant mortality. Country is indexed by i and five-year time period by t. Consistent with the emphasis on early childhood there is a lag of four periods (20 years) between the explanatory variables and the height outcome. Because of the strong trends in many of the variables, I use deviations from trend obtained from regressions with fixed country effects. Panel unit root tests indicate that the variables used in the regressions are I(0); these are reported in Appendix Table A1. The regressions in Table 3 include dummies for country and for breaks in the series. Although we must be cautious about inferring causal effects, the 20-year time lag, eliminating the trends, and using fixed effects provides some reassurance.

The first column of Table 3 uses as explanatory variables the log of per capita income and a crude measure of inequality—a representation of the health production function. The GDP measure is taken from Maddison's database and

Table 3 Proximate determinants of adult height

	(1)	(2)	(3)	(4)
Log GDP per capita	1.759	1.811	1.704	0.887
	(5.55)	(5.77)	(5.49)	(2.43)
Inequality	0.001	0.010	0.015	
	(0.06)	(0.49)	(0.77)	
Family size		−0.492	−0.537	−0.365
		(2.96)	(3.50)	(2.39)
Years of education			0.214	0.205
			(2.34)	(2.50)
Infant mortality rate (per 100 births)				−0.562
				(7.78)
Infant mortality rate squared				0.013
				(5.66)
R-squared	0.152	0.175	0.194	0.383
RESET	0.88	1.13	2.10	1.94
Time dummies	3.31	3.42	3.61	1.42
Cointegration	4.43	4.04	4.20	4.39
Countries	15	15	15	15
Observations	267	267	267	267

Note: Estimated with country fixed effects; robust t-statistics in parentheses. RESET is the F-statistic for the Ramsey regression specification error; 'time dummies' is the F-statistic for the exclusion of period dummies; 'cointegration' is the inverse normal Dickey Fuller test against the null that all panel elements contain a unit root.

the measure of inequality is the Gini coefficient of household income, based on Bourguignon and Morrisson (2002). The income effect implies that a 10% increase in income per capita adds 0.17 cm to average height—similar to the magnitudes found in previous studies. This is a powerful effect that would account for an increase in average height of 0.8 cm from 1871–75 to 1911–15 and 3.4 cm over the whole century. By contrast, the coefficient on inequality is highly insignificant, perhaps because the variable is heavily interpolated.

Column (2) adds a proxy for average family size. This is represented by the ratio of children aged 0–14 to married females aged 20–44 (similar results are obtained with ages 20–54 in the denominator). Family size takes a significant negative coefficient, which is consistent with the idea of a quality-quantity trade-off in child health. However, a decline of one child per married women of childbearing age adds only 0.5 cm to average height. Column (3) adds average years of education for the parents' generation. This variable is calculated from the number of children of the previous generation attending school (see Appendix). It takes a positive coefficient as predicted, and it implies that one additional year of parental education increases height by 0.2 cm.

Column (4) adds linear and squared terms for infant mortality (as deviations from trend). The overall effect of infant mortality on height is the balance of two effects (Bozzoli *et al.* 2009). If infant mortality eliminates the weakest, then a rise in infant mortality leads to healthier and hence taller survivors. By contrast, the scarring effect, where infant mortality stands as an indicator for the general childhood disease environment, leads to a negative correlation between the infant mortality and height. In their empirical results for cohorts in postwar Europe, Bozzoli *et al.* (2009) find a convex relationship, which they estimate as quadratic. The interpretation is that, as infant mortality fell, the decline in scarring increasingly outweighed the decline in selection. The result in column (3) is consistent with that argument, although there could be other interpretations. The linear and squared terms are both highly significant, and the U-shaped function reaches a minimum at an infant mortality rate of 22%. This implies that infant mortality had a modest effect on height in the nineteenth century, but this effect became more negative in the twentieth century as infant mortality fell.[7]

In the presence of infant mortality, the coefficient on per capita income is radically reduced. This implies that about half of the effect of the growth in living standards on height works through the disease environment. It does not seem to be the result of the particular functional forms chosen. The evidence suggests that the log of income outperforms a quadratic function of income and

[7] At the mean of infant mortality in the raw data (10%) a 1 percentage point decline in infant mortality increases height by about 0.3 cm. This is slightly larger effect than the 0.25 cm obtained for the heights of children in British towns between 1910 and 1950 (Hatton, 2011). In their country-level estimates Bozzoli *et al.* (2009) find an average effect of 0.6 cm, using postneonatal mortality, which is about half of total infant mortality.

Table 4 Contributions to increase in height by period and region

Region	Log GDP per capita	Infant mortality	Family size	Education	Sum	Height increase
			1871–75 to 1911–15			
North	0.45	1.43	−0.04	0.31	2.15	3.83
Middle	0.40	−0.05	0.05	0.48	0.88	2.01
South	0.35	0.74	0.03	0.23	1.35	2.70
			1911–15 to 1951–55			
North	0.67	2.62	0.52	0.40	4.20	5.89
Middle	0.32	2.94	0.40	0.33	3.99	6.18
South	0.42	2.39	0.19	0.20	3.20	3.97
			1951–55 to 1976–80			
North	0.70	0.84	0.11	0.28	1.93	2.57
Middle	0.82	1.50	0.07	0.17	2.56	2.97
South	1.01	1.84	0.06	0.62	3.52	4.23
			1871–75 to 1976–80			
North	1.82	4.88	0.59	0.78	8.08	11.96
Middle	1.59	4.39	0.52	0.98	7.47	11.17
South	1.75	5.21	0.27	1.05	8.27	11.06

that the quadratic function of infant mortality outperforms either a linear or logarithmic function.[8] Also, the RESET test does not suggest mis-specification, and with infant mortality included, the test for the full set of period dummies is insignificant. Nor is there evidence that periods of wartime stress had any effect; a variable for years of war for the countries directly affected was not significant.[9]

4.2 Decomposition of proximate effects

Before proceeding to some further tests, it is worth examining the effect of the variables included so far. Table 4 shows the contribution of each of the explanatory variables in three subperiods and overall. Here I apply the coefficients in column (4) of Table 3 to the overall change in each variable (including the trend) for each country and then take the average for each of the three groups of countries. The first column of Table 4 shows that per capita GDP growth added about half a centimetre to height from 1871–75 to 1911–15 in all three groups. The fall in infant mortality, which takes account of both the linear and squared terms, had substantial effects in the North and South but only modest effects in middle Europe. Although family size had almost no effect, the gradual rise in education added half a centimetre in Middle Europe and slightly less in the North and the South.

[8] Using the regression in column (4) of Table 3, the F-statistic for the exclusion of linear and squared income terms is 0.94 whilst the F-statistic for the exclusion of the log of infant mortality is 1.27.

[9] This variable is the fraction of years in each quinquennium that the country was at war, and the t-statistic is 0.40.

During the transwar period, income effects remained modest except in the North, but the fall in infant mortality added nearly 3 cm to height in middle Europe with only slightly smaller effects in the North and the South. Thus the improvement in the disease environment accounts for much of the boost to the trend in height during the transwar period. The fall in family size added to this, particularly in the North and middle European countries, whereas the modest growth of education did not. In the postwar period (a shorter period than the other two) income and infant mortality each made substantial contributions, and family size added little. In the South, the spectacular growth in per capita income, the fall in infant mortality, and the rise in education all contributed to the convergence on the middle and the North.

As the bottom panel of Table 4 shows, over the whole period of more than a century, the fall in infant mortality was the largest single influence, adding around 4 to 5 cm to the increase in height. Per capita income added 1 to 2 cm, and education added around 1 cm. The right-hand columns show that over the century as a whole these influences accounted for two-thirds to three-quarters of the overall increase in height. Interestingly the share of growth that is accounted for by these variables increases from around half in the prewar era to about four-fifths in the postwar period. It is also worth noting that the convergence in infant mortality did not contribute to cross-country convergence in height until the postwar period. The effects of infant mortality alone increased the standard deviation of height by 0.4 between 1871–75 and 1911–15 (10 countries) and by 0.2 between 1911–15 and 1951–55 (11 countries), but then reduced it by 0.5 between 1951–55 and 1976–80 (15 countries).

4.3 Social services and urbanization

As we have seen, much of the long-term upwards trend in height can be explained by income per capita and infant mortality. So what role is there for policy-related variables such as health and social services and the improving urban environment? How did these interact, if at all, with the effects identified so far?

To test for the effects of health and social services the first column of Table 5 adds two variables. The first is simply a dummy for the presence of a universal health care system. Although this often occurred in stages, the variable switches from 0 to 1 for the most important single transition, such as the establishment of the UK National Health Service in 1948. The second is government expenditure on social services as a percentage of GDP. This includes public expenditure on welfare and housing as well as health, so it reflects a much broader portfolio of public provision, including an element of redistribution.[10] These (and other variables added later) are aligned with cohort birth years. As column (1) shows, neither of

[10] A possible concern is that social services might be introduced in response to health outcomes. However, in their cross-country analysis of the introduction of social insurance and of health expenditures, Cutler and Johnson (2004) found no effects for GDP per capita, urbanization, or a range of other variables suggested by theories of public sector expansion.

Table 5 Effects of social expenditure and urbanization on height

	(1)	(2)	(3)	(4)
Log GDP per capita	0.745	0.672	0.234	1.381
	(2.20)	(2.01)	(2.13)	(4.79)
Family size	−0.363	−0.127	−0.105	−0.393
	(2.43)	(0.80)	(0.65)	(2.42)
Education years of parents' generation	0.180	0.351	0.374	0.246
	(2.21)	(4.00)	(3.84)	(3.36)
Infant mortality rate (per 100 births)	−0.474	−0.478	−0.493	
	(6.51)	(6.54)	(7.37)	
Infant mortality squared	0.011	0.013	0.014	
	(4.54)	(4.80)	(5.63)	
Universal health care dummy	0.248	0.339	0.386	0.744
	(1.26)	(1.69)	(1.90)	(3.42)
Expenditure on social services (percent of GDP)	0.010	0.490	0.471	0.462
	(0.26)	(3.70)	(3.59)	(3.74)
Social expenditure × education years		−0.049	−0.050	−0.047
		(3.78)	(3.45)	(3.50)
Percent urban (in cities > 50,000)			0.009	−0.028
			(0.55)	(1.43)
Railway miles/urban population			0.038	0.085
			(1.07)	(2.28)
R-squared	0.403	0.440	0.442	0.330
RESET	1.32	2.71	3.04	0.03
Time dummies	1.35	1.35	1.89	3.59
Cointegration	4.17	4.30	4.43	3.86
Countries	15	15	15	15
Observations	264	264	264	264

Note: Estimated with country fixed effects; robust *t*-statistics in parentheses. RESET is the *F*-statistic for the Ramsey regression specification error; 'time dummies' is the *F*-statistic for the exclusion of period dummies; 'cointegration' is the inverse normal Dickey Fuller test against the null that all panel elements contain a unit root.

these variables is significant, although they both take positive signs. Similarly, a variable for the percentage of the adult population covered by some form of medical benefit insurance proved to be insignificant. This is not shown because the variable is only available for 12 of the 15 countries. But the result is hardly surprising as such benefits did not cover infants and children.

It is sometimes suggested that social services confer greater health benefits on more educated populations—those who can make the best use of them. On the other hand, education and welfare services could be substitutes—the more educated the population, the better they can look after their children's health without recourse to social services. Column (2) of Table 5 adds an interaction between the education of the parent's generation and the social services expenditure share. This turns out to be strongly negative, and in the presence of the interaction, the main effects of education and social services are increased, especially the latter. This result implies that education and social services were important contributors to height in the late nineteenth and early twentieth centuries, but by the postwar period the main effects are almost entirely offset by the interaction effect. A negative interaction effect between maternal education and community services has been identified in micro-level studies of developing countries such as Brazil and the Philippines (Barrera, 1990; Thomas *et al.*, 1991). More recent studies have emphasized the importance of maternal knowledge of nutrition and hygiene for child health, especially for low-educated mothers (Christiaensen and Alderman, 2004; Block, 2007). Although more education may be helpful, much of the relevant knowledge is obtained through health service workers (Glewwe, 1999). In the context of European development, it is possible that expanding health knowledge purveyed by welfare services made families less dependent on their own knowledge or intuition.

As noted, the historical literature also suggests that urbanization had negative effects on child health in the nineteenth century. Urbanization is measured as the proportion of the population living in towns with a population of 50,000 or more, although it makes little difference if a cutoff of 100,000 is used instead. It has also been suggested that transport infrastructure was a key element in improving access to fresh foodstuffs, an effect that is proxied by the ratio of miles of railway track to urban population. In column (3) of Table 5 the coefficients on both variables are insignificant. One reason that these effects are weak may be that their effects on height, via the disease environment, is being captured by infant mortality. Similar arguments may also apply to the effects of social and health services—that their principal effects work though the disease environment. Accordingly column (4) of Table 5 excludes the infant mortality terms. This increases the size of the income coefficient (as was clear from Table 3), suggesting that infant mortality is influenced by GDP per capita. Also notable is the increase in the size and significance of family size and the dummy for universal health care. The coefficient on percent urban now becomes negative, and that on railway miles increases in size and significance. Its effect was largest in the prewar and early transwar years when the railway mileage increased more rapidly than the urban population.

These results should be regarded as tentative. Some of the data used here are crude proxies for the indicators that we would really like to measure. In particular, expenditure on public social services is a broad measure by function, but it reflects only expenditures by the central government. Also, different types of social spending have different effects on health and often follow different trends (Gauthier, 1999). Not surprisingly the development literature is divided about the effect of health spending on infant mortality and on the disease environment more generally (Filmer and Pritchett, 1999; Hanmer *et al.*, 2003). Nevertheless, there is some evidence in support of the view that the effect of health expenditures depends on a range of factors, including education.

5. Conclusion

The main findings in this article can be summarized as follows. New data show that average male height in Europe increased by about 11 cm in the century from the

1870s—representing an unprecedented improvement in health status. In northern and middle European countries there was a distinct quickening in the pace of advance in the period spanning the two world wars and the Great Depression, which largely predates the modern medicine and national health services. In southern Europe height increased fastest in the postwar period. There is evidence of a concave health production function, but the effects of inequality are not robust. Education had a positive effect on height and family size a negative effect, consistent with the quality-quantity trade-off. The evidence suggests that improvements in the disease environment, as reflected in infant mortality, is the single most important factor driving the increase in height. This accounts for much of the acceleration during the transwar period. Social services and health systems made a modest contribution to the overall increase in height. One reason is that education and expenditure on social services seem to be substitutes. Transport infrastructure also contributed to health and height, especially in the prewar era. But a substantial part of the overall upwards trend in height is not explained—in the absence of infant mortality, about a half. There are other important factors that are not easily measured, including medical advances and practices, and especially better parental knowledge of the effects of nutrition and hygiene on children's health.

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References

Alter, G., Neven, M., and Oris, M. (2004) Stature in transition: a micro-level study from nineteenth-century Belgium, *Social Science History*, **28**, 231–47.

Barker, D.J.P. (1995) Foetal origins of coronary heart disease, *British Medical Journal*, **311**, 171–74.

Barrera, A. (1990) The role of maternal schooling and its interaction with public health programs in child health production, *Journal of Development Economics*, **32**, 69–91.

Baten, J. (2009) Protein supply and nutritional status in nineteenth century Bavaria, Prussia and France, *Economics and Human Biology*, **7**, 165–80.

Baten, J. and Blum, M. (2012) Growing tall but unequal: new findings and new background evidence on anthropometric welfare in 156 countries, 1810–1989, *Economic History of Developing Regions*, **27**, S66–85.

Baten, J. and Murray, J.E. (2000) Heights of men and women in 19th century Bavaria: economic, nutritional and disease influences, *Explorations in Economic History*, **37**, 351–69.

Baten, J. and Wagner, A. (2003) Autarchy, market disintegration and health: the mortality and nutritional crisis in Nazi Germany, 1933–1937, *Economics and Human Biology*, **1**, 1–28.

Beard, A.S. and Blaser, M.J. (2002) The ecology of height: the effect of microbial transmission on human height, *Perspectives in Biology and Medicine*, **45**, 475–98.

Bell, F. and Millward, R. (1998) Public health expenditures and mortality in England and Wales, 1870–1914, *Continuity and Change*, **13**, 221–49.

Block, S.A. (2007) Maternal knowledge versus schooling as determinants of child micronutrient status, *Oxford Economic Papers*, **59**, 330–53.

Bourguignon, F. and Morrisson, C. (2002) Inequality among world citizens: 1820–1992, *American Economic Review*, **92**, 727–44.

Bozzoli, C., Deaton, A.S., and Quintana-Domeque, C. (2009) Child mortality, income and adult height, *Demography*, **76**, 647–69.

Cage, R.A. and Foster, J. (2002) Overcrowding and infant mortality: a tale of two cities, *Scottish Journal of Political Economy*, **49**, 129–49.

Case, A. and Paxson, C. (2010) Causes and consequences of early life health, *Demography*, **47(Suppl.)**, S65–85.

Christiaensen, L. and Alderman, H. (2004) Child malnutrition in Ethiopia: can maternal knowledge augment the role of income? *Economic Development and Cultural Change*, **52**, 287–312.

Cole, T.J. (2000) Secular trends in growth, *Proceedings of the Nutrition Society*, **59**, 317–24.

Cole, T.J. (2003) The secular trend in human physical growth: a biological view, *Economics and Human Biology*, **1**, 161–68.

Costa, D. (1998) Unequal at birth: a long term comparison of income and birth weight, *Journal of Economic History*, **58**, 987–1009.

Crimmins, E.M. and Finch, C.E. (2005) Infection, inflammation, height and longevity, *Proceedings of the National Academy of Science*, **103**, 498–503.

Cutler, D.M. and Johnson, R. (2004) The birth and growth of the social insurance state: explaining old age and medical insurance across countries, *Public Choice*, **120**, 87–121.

Cutler, D. and Miller, G. (2005) The role of public health improvements in health advances: the twentieth century United States, *Demography*, **42**, 1–22.

Cutler, D., Deaton, A., and Lleras-Muney, A. (2006) The determinants of mortality, *Journal of Economic Perspectives*, **20**, 97–120.

Easterlin, R.A. (1999) How beneficent is the market? A look at the modern history of mortality, *European Review of Economic History*, **3**, 257–94.

European Parliament (1998) Health care systems in the EU a comparative study, http://www.europarl.europa.eu/workingpapers/saco/pdf/101_en.pdf (accessed 3 October 2010).

Filmer, D. and Pritchett, L. (1999) The impact of public spending on health: does money matter? *Social Science and Medicine*, **49**, 1309–23.

Flora, P. (1983) *State, Economy and Society in Western Europe, 1815–1975*, vol. 1, Macmillan, London.

Flora, P., Kraus, F., and Pfenning, W. (1987) *State, Economy and Society in Western Europe, 1815–1975*, vol. 2, Macmillan, London.

Floud, R. (1994) The heights of Europeans since 1750: a new source for European economic history, in J. Komlos (ed.) *Stature, Living Standards and Economic Development*, University of Chicago Press, Chicago.

Floud, R., Wachter, K., and Gregory, A. (1990) *Height, Health and History: Nutritional Status in the United Kingdom, 1750–1980*, Cambridge University Press, Cambridge.

Floud, R., Fogel, R.W., Harris, B., and Hong, S.C. (2011) *The Changing Body: Health, Nutrition and Human Development in the Western World since 1700*, Cambridge University Press, Cambridge.

Foster, J.M., Chinn, S., and Rona, R.J. (1983) The relation of the height of primary school children to population density, *International Journal of Epidemiology*, **12**, 199–203.

Garcia, J. and Quintana-Domeque, C. (2007) The evolution of adult height in Europe: a brief note, *Economics and Human Biology*, **5**, 340–34.

Gauthier, A.H. (1999) Historical trends in state support for families in Europe (post-1945), *Children and Youth Services Review*, **21**, 937–65.

Glewwe, P. (1999) Why does mothers' schooling raise child health in developing countries?, Evidence from Morocco, *Journal of Human Resources*, **34**, 124–59.

Hanmer, L., Lesink, R., and White, H. (2003) Infant and child mortality in developing countries: analysing the data for robust determinants, *Journal of Development Studies*, **40**, 101–18.

Hatton, T.J. (2011) Infant mortality and the health of survivors: Britain 1910–1950, *Economic History Review*, **62**, 951–72.

Hatton, T.J. and Bray, E. (2010) Long run trends in the heights of European men, 19th and 20th centuries, *Economics and Human Biology*, **8**, 405–13.

Hatton, T.J. and Martin, R.M. (2010) Fertility decline and the heights of children in Britain, 1886–1938, *Explorations in Economic History*, **47**, 505–19.

Hauspie, R.C., Vercauteren, M., and Susanne, C. (1996) Secular changes in growth, *Hormone Research*, **45(Suppl.)**, 8–17.

Humphries, J. and Leunig, T. (2009) Cities, market integration and going to sea: stunting and the standard of living in early nineteenth century England and Wales, *Economic History Review*, **62**, 458–78.

Jacobs, J. and Tassenaar, V. (2004) Height, income and nutrition in the Netherlands in the second half of the nineteenth century, *Economics and Human Biology*, **2**, 181–95.

Koepke, N. and Baten, J. (2005) The biological standard of living in Europe during the last two millenia, *European Review of Economic History*, **9**, 61–95.

Kuh, D. and Wadsworth, M. (1989) Parental height, childhood environment, and subsequent adult height in a national birth cohort, *International Journal of Epidemiology*, **18**, 663–68.

Lindert, P.H. (2004) *Growing Public: Social Spending and Economic Growth since the Eighteenth Century*, vol. 2, Cambridge University Press, New York.

Mackenbach, J.P. (1996) The contribution of medical care to mortality decline: McKeown revisited, *Journal of Clinical Epidemiology*, **49**, 1207–13.

María-Dolores, R. and Martínez-Carrión, J.M. (2011) The relationship between height and economic development in Spain, 1850–1958, *Economics and Human Biology*, **9**, 30–44.

Martínez-Carrión, J.M. and Moreno-Lázario, J. (2007) Was there an urban height penalty in Spain, 1840–1913? *Economics and Human Biology*, **5**, 144–64.

McEvoy, B.P. and Visscher, P.M. (2009) Genetics of human height, *Economics and Human Biology*, **7**, 294–306.

McKeown, T. (1976) *The Modern Rise of Population*, Edward Arnold, London.

McKeown, T. (1979) *The Role of Medicine: Dream, Mirage or Nemesis?*, Blackwell, Oxford.

Millward, R. and Baten, J. (2010) Population and living standards 1914–1945, in S.N. Broadberry and K.H. O'Rourke (eds) *The Cambridge Economic History of Modern Europe*, vol. 2, Cambridge University Press, Cambridge.

Mitchell, B.R. (1992) *International Historical Statistics: Europe*, Macmillan, London.

Mokyr, J. (2000) Why 'more work for mother?' Knowledge and household behavior, 1870–1945, *Journal of Economic History*, **60**, 1–41.

Peracchi, F. (2008) Height and economic development in Italy, *American Economic Review, Papers and Proceedings*, **98**, 475–81.

Peracchi, F. and Arcaleni, E. (2011) Early life environment, height and BMI of young men in Italy, *Economics and Human Biology*, **9**, 251–64.

Power, C. and Manor, O. (1995) Asthma, enuresis and chronic illness: long term impact on height, *Archives of Disease in Childhood*, **73**, 298–304.

Preston, S.H. (1975) The changing relation between mortality and the level of economic development, *Population Studies*, **29**, 231–48.

Quintana-Domeque, C., Bozzoli, C., and Bosch, M. (2011) Infant mortality, and adult stature in Spain, *Social Science & Medicine*, **72**, 1893–903.

Rona, R.J. and Florey, C. du V. (1980) National study of health and growth: respiratory symptoms and height in primary schoolchildren, *International Journal of Epidemiology*, **9**, 35–43.

Rosenberg, M. (1988) Birth weights in three Norwegian cities, 1860–1984: secular trends and influencing factors, *Annals of Human Biology*, **15**, 275–88.

Schmidt, I.M., Jørgensen, M.H., and Michaelsen, K.F. (1995) Height of conscripts in Europe: is postneonatal mortality a predictor? *Annals of Human Biology*, **22**, 57–67.

Schneider, R. (1996) Historical note on height and parental consumption decisions, *Economics Letters*, **50**, 279–83.

Silventoinen, K. (2003) Determinants of variation in adult body height, *Journal of Biosocial Science*, **35**, 263–85.

Silventoinen, K., Kaprio, J., Lahelma, E., and Koskenvuo, M. (2000) Relative effect of genetic and environmental factors on body height: differences across cohorts among Finnish men and women, *American Journal of Public Health*, **90**, 627–30.

Spijker, J.A.J., Cámara, A.D., and Blanes, A. (2012) The health transition and biological living standards: adult height and mortality in 20th century Spain, *Economics and Human Biology*, **10**, 276–88.

Steckel, R.H. (1995) Stature and the standard of living, *Journal of Economic Literature*, **33**, 1903–40.

Steckel, R.H. (1998) Birth weights and stillbirths in historical perspective, *European Journal of Clinical Nutrition*, **52S2**, 16–20.

Steckel, R.H. (2004) New light on the 'Dark Ages': the remarkably tall stature of northern European men during the medieval era, *Social Science History*, **28**, 211–29.

Steckel, R.H. (2009) Heights and human welfare: recent developments and new directions, *Explorations in Economic History*, **46**, 1–23.

Stegl, M. and Baten, J. (2009) Tall and shrinking Muslims, short and growing Europeans: the long run welfare development of the Middle East, 1850–1980, *Explorations in Economic History*, **46**, 132–46.

Tanner, J.M. (1962) *Growth at Adolescence*, Blackwell, Oxford.

Thomas, D., Strauss, J., and Henriques, M.H. (1991) How does mother's education affect child height? *Journal of Human Resources*, **26**, 183–211.

Twarog, S. (1997) Heights and living standards in Germany, 1850–1939: the case of Württemberg, in R.H. Steckel and R. Floud (eds) *Health and Welfare during Industrialization*, University of Chicago Press, Chicago.

Weir, D.R. (1993) Parental consumption decisions and child health during the early French fertility decline, 1790–1914, *Journal of Economic History*, **53**, 259–74.

Winegarden, C.R. and Murray, J.E. (1998) The contributions of early health-insurance programs to mortality declines in pre–World War I Europe: evidence from fixed-effects models, *Explorations in Economic History*, **35**, 431–46.

Winegarden, C.R. and Murray, J.E. (2004) Effects of early health-insurance programs on European mortality and fertility trends, *Social Science and Medicine*, **58**, 1825–36.

Appendix: Data

Heights of adult males: Sources and construction are described in detail in Hatton and Bray (2010). The coverage by country and period is as follows. Austria: 1856–60 to 1911–15 and 1936–40 to 1976–80; Belgium: 1866–70 to 1976–80; Denmark: 1856–60 to 1976–80; Finland: 1941–45 to 1976–80; France: 1856–60 to 1976–80; Germany 1856–60 to 1891–95 and 1926–30 to 1976–80; Greece: 1926–30 to 1976–80; Ireland: 1971–75 to 1901–5 and 1951–55 to 1976–80; Italy: 1856–60 to 1976–80; the Netherlands: 1856–60 to 1976–80; Norway: 1861–66 to 1976–80; Portugal 1911–15 to 1976–80; Spain 1871–75 to 1976–80; Sweden: 1856–60 to 1976–80; Great Britain: 1861–65 to 1976–80.

GDP per capita: From Maddison at http://www.ggdc.net/maddison/ (accessed 18 August 2009). Five-year averages are calculated from annual data.

Inequality: Calculated from data underlying Bourguignon and Morrisson at http://www.delta.ens.fr/XIX/#1820 (accessed 23 October 2010). The Gini coefficient is constructed from income shares by decile. Where the data are presented for groups of countries, the values were applied to each country within the group. Observations for missing dates are filled in by linear interpolation between benchmarks at 20-year intervals to 1950 and 10-year intervals thereafter.

Family size: This variable is constructed from census data on population by age and the share of females married. Population data by five-year age groups is taken from Mitchell (1992). The proportion of females married by age group is from Flora *et al.* (1987), supplemented by the UN *Demographic Yearbook* 1960, Table 10, and 1982, Table 40, and additional data for Spain from http://www.ine.es/en/inebmenu/mnu_cifraspob_en.htm (accessed 3 September 2009). Ratios were obtained as the number of children aged 0–14 divided by the number of married females aged either 20–44 or 20–59. These ratios were linearly interpolated between census years.

Education: For 10 countries the source is Flora (1983). Participation rates for the relevant age groups are listed separately for primary, post-primary, lower secondary, and higher secondary. These ratios are combined to give the number of primary and secondary pupils as a proportion of the age group 5–19 in the year closest to the beginning of each five-year period. Multiplying by the number of years of age (15) gives a cross-sectional approximation of the average number of years of education. For Greece, Ireland, Portugal, and Spain the calculation is based on dividing the total number at primary and secondary school by the population aged 5–19 using data from Mitchell (1992). The same source is used for England and Scotland but before 1900 the series are adjusted based on Lindert (2004), pp. 147–52. This variable is then lagged two periods (10 years) to give an estimate of education for the parents of each cohort.

Infant mortality: All infant mortality rates are from Mitchell (1992), pp. 117–22. Five-year averages calculated from annual data.

Share of social services in GDP: Expenditure on health, education, and housing as a share of GDP in nominal terms calculated from data for 12 countries reported in Flora (1987). Observations for Spain based on national accounts data kindly supplied by Leandro Prados. Data for Portugal taken from N. Valério, ''Portuguese Historical Statistics'' (2001), at http://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=138364&PUBLICACOESmodo=2 (accessed 15 December 2009). Expenditure on social and educational services (Table 9.5) divided by nominal GDP (Tables 6.5 and 6.6). Data for Greece from National Statistical Office of Greece (Greek National Accounts), kindly supplied by Apostolis Philippopoulos. These data are for central government expenditures and omit local government expenditures, which were especially important for most countries before World War I. The data are for the year closest to the beginning of each five-year period, with interpolations where necessary. In some cases backwards extrapolations were made for the mid- to late nineteenth century when social expenditures were typically less than 0.5% of GDP.

Health system coverage: Universal health system dummy derived from European Parliament (1998). Number covered for medical benefits under public health insurance schemes as a percentage of the population aged 15 and over. Data for 12 countries are from Flora (1983).

Share of population urban: These data are taken from the Cross National Time Series database (assembled by A.C. Banks), supplied by the Inter-university Consortium for Political and Social Research, Ann Arbor, MI. Because these are based largely on census sources, we take the first year of each five-year period, with interpolations where necessary.

Railway track miles per urban resident: Railway miles taken from Mitchell (1992), pp. 655–66, divided by the urban population.

Table A1 Descriptive statistics

Variable	No. of Obs	Mean 1856–60 to 1976–80	Standard deviation	Unit root test	Mean 1856–60 to 1906–10	Mean 1911–15 to 1946–50	Mean 1950–55 to 1976–80
Height (cm)	308	171.57	4.77	5.17	167.88	171.17	176.20
GDP per capita (1990 international dollars)	372	4385.81	3344.56	3.95	2241.40	3581.36	8071.79
Inequality (top 10% of income)	400	42.82	6.95	5.53	52.21	43.96	35.17
Family size (children / married women)	325	2.69	0.68	6.76	3.25	2.62	2.10
Education years (parent's generation)	326	6.85	1.86	3.88	5.30	6.39	7.97
Infant mortality (percent)	370	10.11	6.68	5.61	16.14	9.21	3.04
Public exp. on social services (% of GDP)	315	3.94	4.29	4.84	0.59	3.13	8.41
Percent of popn. urban (in cities > 50,000)	366	20.57	11.44	4.15	12.73	22.17	29.32
Railway miles/urban population	343	0.47	0.41	8.27	0.55	0.53	0.29

Note: Unit root test is the inverse normal statistic for the augmented Dicky Fuller test with drift and with cross-sectional means and linear trends removed. All values in the table reject the null hypothesis at the 5% level that all panels contain a unit root.