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Timothy J. Hatton, Australian National University, University of Essex and CEPR

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Centre for Economic Policy Research
77 Bastwick Street, London EC1V 3PZ, UK
Tel: (44 20) 7183 8801, Fax: (44 20) 7183 8820
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

How have Europeans Grown so Tall?*

Increases in human stature are seen as a key indicator of improvement in the average health of populations. The literature associates stature with a variety of socioeconomic variables, and much of the focus is on the nineteenth century and on the last 50 years. In this paper I present and analyse a new dataset for the average height of adult male cohorts, from the mid-nineteenth century to 1980, in fifteen European countries. In little more than a century average height increased by 11cm--representing a dramatic improvement in health. Interestingly, there was a distinct acceleration in the period spanning the two World Wars and the Great Depression. I examine the influence of socioeconomic variables on height through the two key channels: nutrition and the disease environment. The evidence suggests that the most important single cause 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 the welfare state spending seem to have been small.

JEL Classification: I12, I38 and N24
Keywords: health, human stature and twentieth century Europe

Timothy J. Hatton
Department of Economics
University of Essex
Colchester CO4 3SQ

Email: hatton@essex.ac.uk

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1. Introduction

One of the most important gains to human welfare in the last 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 little more than a century the average height of young adult European males has increased by about 11 centimetres. Although average height has fluctuated across the centuries, the increase since the late nineteenth century has been truly unprecedented. This paper asks how that happened. What were the socioeconomic underpinnings to such explosive growth? Through what mechanisms did they operate? And did public policy play a role?

The last 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 focused 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 for example Steckel, 1995, 2009). While this literature has produced a variety of important insights, it often overlooks the period that has seen the most rapid improvement in health—the first half of the twentieth century. 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 paper first sets out to document the dramatic increase in height using a new dataset 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 embracing the two World Wars and the Great Depression. There follows a review of the literature than focuses 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. But the most important single influence is the improvement in the disease environment as reflected by the decline infant mortality. This has a non-linear effect and accounts for much of the spurt in height after 1911. Some of this upward shift is associated with improvement in the urban environment and the growth of the welfare state 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

In order to track average heights over a long period, we have pieced together data from a variety of sources. The database of average adult heights for five-year birth cohorts used here covers 15 European countries, going back were possible to the middle of the nineteenth century. It builds on the work of many others and 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 ten countries by Garcia and Quintana-Domeque (2007), adding five more countries. In some cases we carry these back using earlier surveys for height by age. But 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.

These data are plotted by birth cohort in Figure 1. Between the birth cohorts of 1871-5 and 1976-80 average male height in these countries increased by 11cm, or about 1cm per decade. It is worth stressing that such a dramatic increase in height over such a short period is truly unprecedented.[1] There is also evidence of a distinct acceleration in growth somewhere 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 1871-5 to 1976-80 and for three major economic eras: 1871-5 to 1911-15 (prewar), 1911-15 to 1951-5 (transwar) and 1951-5 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 notable that for most countries in Northern and Western Europe, the fastest period of growth is the transwar period, a feature that has been obscured by the gaps between the two literatures noted above. By Contrast, southern Europeans, who were considerably shorter at the outset, experienced the 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 1871-5 and 1911-15 (10 countries)

[1] Using evidence from bones, Steckel (2004) finds that average heights fell by more than 6 cm between early medieval times and the 17th-18th centuries, not regaining their former level until the beginning of the twentieth century. In their study of height in Europe over two millennia, Koepke and Baten (2005) find a more modest decline. The maximum change (up or down) between any two adjacent centuries is about 2 cm.

and by 0.9 between 1915 and 1951-55 (11 countries) and then fell by 0.7 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, Netherlands, Norway, Sweden), Middle (Austria, Belgium, Germany, Great Britain, Ireland) and South (France, Italy, Greece, Portugal, Spain). Table 2 presents regressions where the time trend increases in increments of 0.5 for every five year period, so that 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, 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 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 last century? And why has the twentieth century differed so much from earlier centuries? Clearly, we can rule out genetic evolution. While 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.[3] 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.[4]

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. While 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. Here 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 focused 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

[2] According to a Finnish study, genetic factors account for about 80 percent of the variance in height (Silventoinen et al., 2000). See also McEvoy and Visscher (2009) for a survey of genetic influences on height and the missing heritability problem (only 5 percentage points of the genetic variation in height has been tracked down in the DNA).

[3] In their study of Polish men Pawlowski et al. (2000) found that taller men have more children, but the differences are relatively small and so the intergenerational effect must be very limited.

[4] 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 upward 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 post-natal influences (Cole, 2000; Hauspie et al., 1996).

of the twentieth century, working class families in the UK were spending 60 percent 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 Figure 1. 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 GDP per capita of Western Europe grew at annual rates of 1.3 percent from 1870 to 1913, 0.9 percent from 1913 to 1951, and 3.5 percent from 1951 to 1980. Spectacular 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 1 as compared to the increase from H_2 to H_3. But it is more difficult to explain why heights increased so strongly in the trans-war period as compared with the forty years before World War 1. According to Figure 1, $H_2 – H_1$ 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 obvious 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 is average income 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.[5]

Since the focus is on conditions during childhood, family structure matters too. If there is a tradeoff 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 the number of children in the household reduced their 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). 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 upward shift in the health production function (Cutler et al., 2006; Easterlin, 1999). These improvements in the health environment are seen most clearly in the steep declines in mortality rates. While improvements of living standards are of some help, most of the increase in life expectancy is due to improvements in the disease environment. This is

[5] It is also notable that that the relative price of food fell over the transwar period, which would favour poorer households. However, that trend may have been muted by substitution towards of poor quality, less nourishing, foods. For the late nineteenth centuryLogan (2006) finds that nutrition was substantially lower in the UK than in the US both because household incomes were lower and because the relative price of food was higher.

illustrated in Figure 1 by the upward 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 bacterium *Helicobacter pylori*, which colonises the stomach and duodenum, and is associated with crowded environments and contaminated water. Chronic infection triggers immune responses that are metabolically demanding and also elevates cortisol levels that can reduce growth by impairing protein synthesis (Crimmins and Finch, 2005, p. 500-1). Studies of UK birth cohorts have found that serious illnesses during childhood can reduce adult height by as much as 1-2cm (Kuh and Wadsworth, 1989; Power and Manor 2005).

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 Figure 3. Infant mortality rates fell from an average of 178 per thousand in 1871-5 to 120 per thousand in 1911-15 and then plummeted to 41 in 1951-5 and 14 in 1976-80. To the extent that infant mortality captures the disease environment, this could have contributed to the acceleration in heights before 1950.

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 that is used here). Using post-neonatal 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 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 a recent study of the effects of declining infant mortality on the average heights of school-age children in British towns between 1910 and 1950 (Hatton, 2011).

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 (in particular milk) and the declining adulteration of processed foods all helped to reduce the risk of disease and death. But perhaps the most important improvements were in sanitary conditions and housing. Several studies have found that sanitary reforms had substantial effects on death rates, and particularly on infant mortality (Bell and Millward, 1998; Cutler and Miller, 2005).[6] 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

[6] McKeown (1976) argued that sanitary reforms had modest effects on death rates in Victorian Britain, but the issue is still contested, see Szreter (1988) and Guha (1994), and for an overview, Colgrove, (2002).

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.

While nineteenth century rural-urban mortality differences were large, the rural height advantage was more modest, typically amounting to one centimeter or less (Alter et al., 2004; Floud et al. 1990, p. 200-6). In some countries they were negative (Martínez-Carrión and Moreno-Lázario, 2007, Twarog 1997, p. 302). 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.[7] 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 medical services.[8]

3.3 Medical knowledge and health services

What about medical advances and public health programmes? McKeown (1976, 1979) famously argued that, as most of the landmark medical discoveries of the twentieth century did not become available until around the Second World War, they cannot have contributed much to the improved health and declining mortality that occurred up to that time.[9] Perhaps more

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[7] For a cross section of towns in England and Wales at the turn of the 20th Century, Williamson (1990, Ch 9) finds a negative correlation between infant mortality and unskilled wages, which he interprets as a disamenity premium. For France in the nineteenth century Weir (1997) finds that the higher meat consumption of city dwellers gave them an overall height advantage.

[8] In more recent data the urban effect seems to vary between countries. This Komlos and Kriwy(2002) find a positive effect in East Germany but not in the West; Komlos and Lauderdale (2006) find a negative effect in the United States while For a discussion of the links between the urban environment and health, see Galea et al (2005).

[9] 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,

important was the expansion of health services and the professionalization of medical practitioners, although progress was slow until well into the twentieth century.[10] Even when new treatments and improved medical expertise became available there was limited access to it. 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 family members. While they may have improved the health outcomes of adults,[11] the effects on children were probably negligible until the advent of national health systems after the Second World War. For most infants and children, access to health care was through maternity services, local clinics and school medical services.

But perhaps the most important treatment given to young children was in the home.[12] Mokyr (2000) argues that improved knowledge of nutrition and the channels through which

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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 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 percent to the total decline in mortality in the century up to 1970.

[10] Examination, diagnosis and treatment of common ailments improved but the means of treating them remained very basic. According to the historian of general practice in Britain “the outcomes of general practice were cost-effective, if not always clinically very effective” (Digby, 1999, p. 221). She also notes that: “In reality, the excitement of the expanding frontiers of surgery was more theoretical than practical. If it was noticeable at all, it would have been in the work of the GP surgeon in the local hospital operating theatre, rather in the more limited kitchen-table surgery of much of the general practitioner’s work (Digby 1999, p. 194). It is also worth noting that the recruitment of more than half of all physicians during the First World War had no negative effect on civilian health (Winter, 2003, p. 186)

[11] 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.

[12] One measure of maternal care is breastfeeding. Examining the heights of German military recruits in 1906 Haines and Kintner (2008) found that breastfeeding added about 1.4cm to average height. However this is not likely to have contributed much to the trend over time.

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 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 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 below.

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 cohorts for 1940 to 1980 Peracchi (2008) also 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 fertility but no effect for income. This contrasts with results for the earlier era where 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 modeled long run annual data for a single country. María Dolores and Martínez Carrión (2009) studied height in Spain from 1850 to 1978. They found that in addition to GDP per capita and infant mortality, height depended positively on consumption of hygiene products and negatively on the relative price of consumption goods. Bosch et al. (2009) identify effects of disease in Spanish provinces for postwar cohorts but find no income effect. Jacobs and Tassenar (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.

4.1 Proximate determinants of height

Here I use the unbalanced panel of adult male heights introduced earlier to examine the contributions of some of the variables mentioned above. Consistent with the emphasis on early childhood, the explanatory variables are aligned with the cohort's birth quinquennium. Details of the data sources and methods of construction are reported in the appendix. Panel unit root tests that include time trends indicate that the variables used in the regressions are I(0); these are also reported in the appendix.

Table 2 presents regressions with fixed effects (random effects is always rejected) and with dummies where there are breaks in country definitions. The first column 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 the measure of inequality is the gini coefficient of household income, based on Bourgignon and Morrison (2002). The income effect implies that a ten percent increase in income per capita adds 0.2 cm to average height—a similar effect to that found in previous studies. Inequality has a negative effect, as expected, and it implies that increasing the top income share by ten percentage points reduces average height by as much as 0.7 cm. While this is consistent with the well-known gradient in height by class and income, this variable is heavily interpolated and it becomes insignificant when other variables are added.

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 strongly supports 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 education increases height by 0.23 cm. It is also worth noting that the time trends in the second and third columns imply a secular increase in height of about 0.7 cm per decade. Thus about 60 percent of the total increase in height over a century or so is unexplained by income, inequality family size and education (regressing height on nothing but a time trend gives a coefficient of 1.13; 't' = 51.5).

Column (4) adds linear and squared terms for infant mortality. This non-linearity is suggested by the model of Bozzoli et al. (2009), where the overall impact of infant mortality on height is the balance of two effects. The selection effect of a fall in infant mortality leads to less healthy and hence shorter survivors. By contrast, the scarring effect, where infant mortality stands as a proxy measure for the general childhood disease environment, leads to a negative correlation between the infant mortality and height. Bozzoli et al. (2009) argue that the scarring effect is likely to dominate at low levels of infant mortality. The selection effect becomes more important at higher levels, as infant mortality cuts deeper into the left hand tail of the health distribution. 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 23 percent. This implies that infant mortality had a modest effect on height in the nineteenth century but that this effect became more negative in the twentieth century as infant mortality fell. This would help to explain why the convergence in infant mortality is not matched by convergence in height. At the mean of infant mortality (10 percent) a one percentage point decline in infant mortality increases height by about 0.3cm.[13]

Adding infant mortality dramatically reduces the coefficient on the time trend. As a result, about two thirds of the overall upward trend is explained. Also the coefficient on per capita income is radically reduced in the presence of infant mortality. That could be the result of the particular functional forms chosen. However, the evidence suggests that the log of income outperforms a quadratic function of income and that the quadratic function of infant mortality outperforms either a linear or logarithmic function.[14] Also, there is little evidence for strong non linearity in the time trend; the z-value on the squared term is 1.4. Nor is there evidence that periods of wartime stress had any effect; a variable for wartime periods was not significant.[15] It is also possible to reject the full set of period dummies (F = 1.51), although there is weak evidence of an upward shift after the Second World War—something that could be due to improved health services.[16]

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[13] This is slightly larger effect than the 0.25cm that I estimated 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 post neonatal mortality which is about half of total infant mortality.

[14] Using the regression in column (4) of Table 3, the F statistic for the exclusion of linear and squared income terms is 0.05 white the F statistic for the exclusion of the log of infant mortality is 1.04.

[15] This variable is the fraction of years in each quinquennium that the country was at war and the z-statistic is 0.24.

[16] The F test for the full set of time dummies is 1.74, which is significant at the 5 percent level but not at 1 percent.

4.21 Decomposition of proximate effects

Before proceeding to some further tests, it is worth examining the impact of the variables included so far. Table 4 shows the contribution of each of the explanatory variables in three time periods and overall. These are constructed by applying the change in an explanatory variable to the coefficient column (4) of Table 3 for each country and then taking 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 1871-5 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. And while 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.

During the transwar period income effects remained modest except in the North but the fall in infant mortality added nearly three centimeters 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 growth of height during the transwar period. The fall in family size added to this, particularly in the North and Middle European countries, while 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, while 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 5cm to the increase in height. Per capita income added about 2cm while education added around 1cm. Table 5 shows the contributions for individual countries, for which the explanatory variable is available over the full period. Overall, the effect of each variable was fairly uniform across countries, but with some deviations.

4.3 Social services and urbanisation

As we have seen much of the long term upward 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? And how did these interact, if at all, with the effects identified so far?

In order to test for the effects of health and social services the first column of Table 6 adds two variables. The first is simply a dummy for the advent of a universal health care service. Although this often occurred in stages, the variable reflects 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 and so it reflects a much broader portfolio of public provision, including an element of redistribution. As column (1) shows, neither of 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 as 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 to 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 6 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. An alternative hypothesis would be that the marginal effects of both education and social service provision have diminished over time. However when this interaction effect is replaced by interactions between education and time and social services and time both coefficients are insignificant ('z' statistics of 1.26 and 0.01 respectively).

This result implies that education and social services were important contributors to height in the late nineteenth and early twentieth century, 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 been identified in micro-level studies of developing countries such as Brazil and the Philippines (Strauss et al., 1991; Barrera, 1990). 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). While 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 above, the historical literature also suggests that urbanisation had negative effects on child health in the nineteenth century, but these effects diminished as the urban environment improved. Urbanisation is measured as the proportion of the population living in towns with a population of 50,000, although it makes little difference if a cutoff of 100,000 is used instead. In column (3) of Table 6 the main effect is negative while the interaction of urbanisation with the time trend is positive, as would be predicted for a secular improvement in the urban environment. Although the magnitudes are plausible, neither effect is significant.

One reason that the urbanisation effect appears to be weak is that its effect 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 6 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. Notable also is the increase in the size and significance of the dummy for universal health care and of the coefficient on the expenditure share of social services. In addition the coefficients on urbanisation and its interaction with time become larger and more significant. In fact, they appear to be somewhat too large. The main effect suggests that the in late 1870s the urban penalty was 9cm and this had become positive 2cm by the late 1970s. Thus the improvement in the urban environment seems to have been more powerful than cross sectional estimates would suggest, perhaps because it captures change in the structure of class and occupation.[17]

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

[17] I am grateful to Avner Offer for this suggestion.

evidence in support of the view that the impact of health expenditures depends on a range of factors, including education.

5. Conclusion

The main findings in this paper can be summarized as follows. New data shows that average male height in Europe increased by about 11cm in the century from the 1870s—representing an unprecedented improvement in health status. In the northern and middle Europe 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 tradeoff. The evidence suggests that 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. Part of the improvement in the disease environment 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.

Data Appendix

Heights of adult males: Sources and construction are described in detail in Hatton and Bray (2009). 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: 1941-5 to 1976-80; France: 1856-60 to 1976-80; Germany 1856-60 to 1891-5 and 1926-30 to 1976-80; Greece: 1926-30 to 1976-80; Ireland: 1971-5 to 1901-5 and 1951-5 to 1976-80; Italy: 1856-60 to 1976-80; Netherlands: 1856-60 to 1976-80; Norway: 1861-6 to 1976-80; Portugal 1911-15 to 1976-80; Spain 1871-5 to 1976-80; Sweden: 1856-60 to 1976-80; Great Britain: 1861-5 to 1976-80.

GDP per capita: From Maddison at: http://www.ggdc.net/maddison/, (accessed 18/8/09). 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 23/10/10). The gini coefficient is constructed from income shares by decile. Where the data is 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, B. R. (1992), *International Historical Statistics: Europe*, London: Macmillan. Proportion of females married by age group from Flora, P., Kraus, F and Pfenning W. (1987), *State, Economy and Society in Western Europe, 1815-1975*, Vol 2, London: Macmillan, supplemented by UN *Demographic Yearbook*, 1960, New York: United Nations, Table 10, and 1982 Table 40, and additional data for Spain from: http://www.ine.es/en/inebmenu/mnu_cifraspob_en.htm. 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: The number of children attending schools is taken from Flora, P. (1983), *State, Economy and Society in Western Europe, 1815-1975*, Vol 1, London: Macmillan. These are listed separately for primary post-primary, lower secondary and higher secondary and also as ratios to the relevant age groups. 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. This variable is then lagged two periods (10 years) to give an estimate of education for the parents of each cohort. For Greece, 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, B. R. (1992), *International Historical Statistics: Europe*, London: Macmillan.

Infant Mortality: All infant mortality rates are from Mitchell, B. R. (1992), *International Historical Statistics: Europe*, London: Macmillan, pp.117-122. Five year averages calculated from annual data.

Share of Social Services in GDP: Calculated from data for 12 countries reported in Flora, P, (1983), *State, Economy and Society in Western Europe, 1815-1975*, Vol , London: Macmillan. Observations for Spain based on national accounts data kindly supplied by Leandro Prados. Data for Portugal taken from Valério, N. (2001), "Portuguese Historical Statistics" at: http://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=138364&PUBLICACOESmodo=2 (accessed 15/12/09). 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. Expenditure on health, education and housing as a share of GDP in nominal terms. These data are for central government expenditures and so they omit local government expenditures which were especially important for most countries before World War 1. The data are for the year closest to the beginning of each five year period, with interpolations where necessary. In some cases backward extrapolations were made for the mid to late nineteenth century when social expenditures were typically less than 0.5 percent of GDP.

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

Health system coverage: Universal health system dummy derived from European Parliament (1998) "Health Care Systems in the EU a Comparative Study" at: http://www.europarl.europa.eu/workingpapers/saco/pdf/101_en.pdf (accessed 3/10/10). Number covered for medical benefits under public health insurance schemes as a percentage of the population aged 15 and over. Data for 12 countries from Flora, P. (1983), *State, Economy and Society in Western Europe, 1815-1975,* Vol 1, London: Macmillan.

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 in centimeters	308	171.57	4.77	4.38	167.88	171.17	176.20
GDP per capita (1990 international dollars)	372	4385.81	3344.56	5.00	2241.40	3581.36	8071.79
Inequality (top ten percent of income)	400	42.82	6.95	5.77	52.21	43.96	35.17
Family size (children /married women)	325	2.69	0.68	7.32	3.25	2.62	2.10
Education years (parent's generation)	306	6.85	1.86	4.80	5.40	6.89	8.29
Infant mortality (percent)	370	10.11	6.68	5.55	16.14	9.21	3.04
Public exp. on social services (% of GDP)	315	3.94	4.29	5.63	0.59	3.13	8.41
Percent of popn. urban (in cities >50,000)	366	20.57	11.44	5.62	12.73	22.17	29.32

Note: Unit root test is the inverse normal statistic for the augmented Dicky Fuller test with drift and with cross sectional means removed. All values in the table reject the null hypothesis at the 1 percent level that all panels contain a unit root.

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Table 1: Increase in height in centimetres per decade

	1871-5 to1976-80	1871-5 to 1911-5	1911-5 to 1951-5	1951-5 to1976-80
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

Table 2: Coefficient on time trend (cm per decade)

	1871-5 to1976-80	1871-5 to 1911-5	1911-5 to 1951-5	1951-5 to1976-80
North (Denmark, Finland, 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

Table 3: Fixed effects regressions on height (in cm)

	(1)	(2)	(3)	(4)
Time trend	0.811 (15.68)	0.736 (12.87)	0.690 (10.54)	0.320 (3.56)
Log GDP per capita	1.691 (5.25)	1.750 (5.50)	1.856 (6.00)	1.056 (3.05)
Inequality	-0.025 (1.39)	-0.014 (0.78)	0.012 (0.64)	
Family Size		-0.549 (3.29)	-0.562 (3.67)	-0.401 (2.68)
Years of education			0.226 (3.06)	0.229 (3.41)
Infant mortality rate (per 100 births)				-0.544 (7.86)
Infant mortality rate squared				0.012 (5.69)
R-squared (within)	0.935	0.937	0.944	0.957
Countries	15	15	15	15
Observations	282	282	270	270

Note: Estimated with country fixed effects; robust 'z' statistics in parentheses.

Table 4: Contributions to increase in height by period and region

Region	Log GDP per capita	Infant mortality	Family size	Education
	1871-75 to 1911-15			
North	0.53	1.48	-0.04	0.34
Middle	0.48	0.09	0.06	0.49
South	0.42	0.83	0.03	0.26
	1911-15 to 1951-55			
North	0.80	2.58	0.57	0.44
Middle	0.38	2.97	0.43	0.28
South	0.50	2.41	0.21	0.16
	1951-5 to 1976-80			
North	0.83	0.81	0.12	0.31
Middle	0.98	1.46	0.07	0.15
South	1.21	1.80	0.06	0.66
	1871-75 to 1976-80			
North	2.16	4.87	0.65	0.87
Middle	1.89	4.52	0.57	0.90
South	2.08	5.28	0.29	1.17

Table 5: Contributions to increase in height from 1871-5 to 1976-80 (in cm)

	Log GDP per capita	Infant mortality	Family size	Education
Austria	2.0	5.2	0.4	1.0
Belgium	1.7	4.8	0.8	0.7
Denmark	2.1	4.7	0.7	1.1
Finland	2.4	5.3	0.5	
France	2.0	5.3	0.2	0.8
Germany	2.0	4.8	0.5	1.0
Great Britain	1.4	4.8	0.6	1.7
Greece				
Ireland		3.3	0.5	
Italy	2.2	5.3	0.4	
Netherlands	1.7	5.6	0.6	0.5
Norway	2.4	4.0	0.7	1.0
Portugal	2.2			
Spain	1.9	5.3		1.2
Sweden	2.2	4.7	0.8	0.9
Average	2.0	4.8	0.6	1.0

Table 6: Effects of Social Expenditure and Urbanisation

	(1)	(2)	(3)	(4)
Time trend (in decades)	0.370 (4.76)	0.354 (4.77)	0.356 (4.75)	0.521 (7.55)
Log GDP per capita	0.876 (2.66)	1.232 (2.75)	1.035 (3.00)	1.519 (5.38)
Family size	-0.395 (2.62)	-0.176 (1.11)	-0.188 (1.21)	-0.253 (1.82)
Education years of parents' generation	0.210 (3.10)	0.362 (5.56)	0.357 (5.01)	0.300 (3.97)
Infant mortality rate (per 100 births)	-0.489 (7.07)	-0.504 (7.30)	-0.436 (5.17)	
Infant mortality squared	0.011 (4.86)	0.013 (3.09)	0.011 (3.94)	
Universal health care dummy	0.236 (1.21)	0.356 (1.84)	0.338 (1.79	0.537 (2.71)
Expenditure on social services (percent of GDP)	0.003 (0.10)	0.506 (3.77)	0.580 (4.17)	0.699 (4.64)
Social expenditure × education years		-0.055 (3.95)	-0.066 (4.35)	-0.080 (4.87)
Percent urban (in cities > 50,000)			-0.058 (1.82)	-0.122 (3.97)
Share urban × time			0.004 (1.60)	0.011 (4.67)
R-squared (within)	0.962	0.964	0.964	0.958
Countries	15	15	15	15
Observations	268	268	268	268

Note: Estimated with country fixed effects; robust 'z' statistics in parentheses.

Figure 1: Adult Male Height by Birth Cohort, 1856-60 to 1876-80

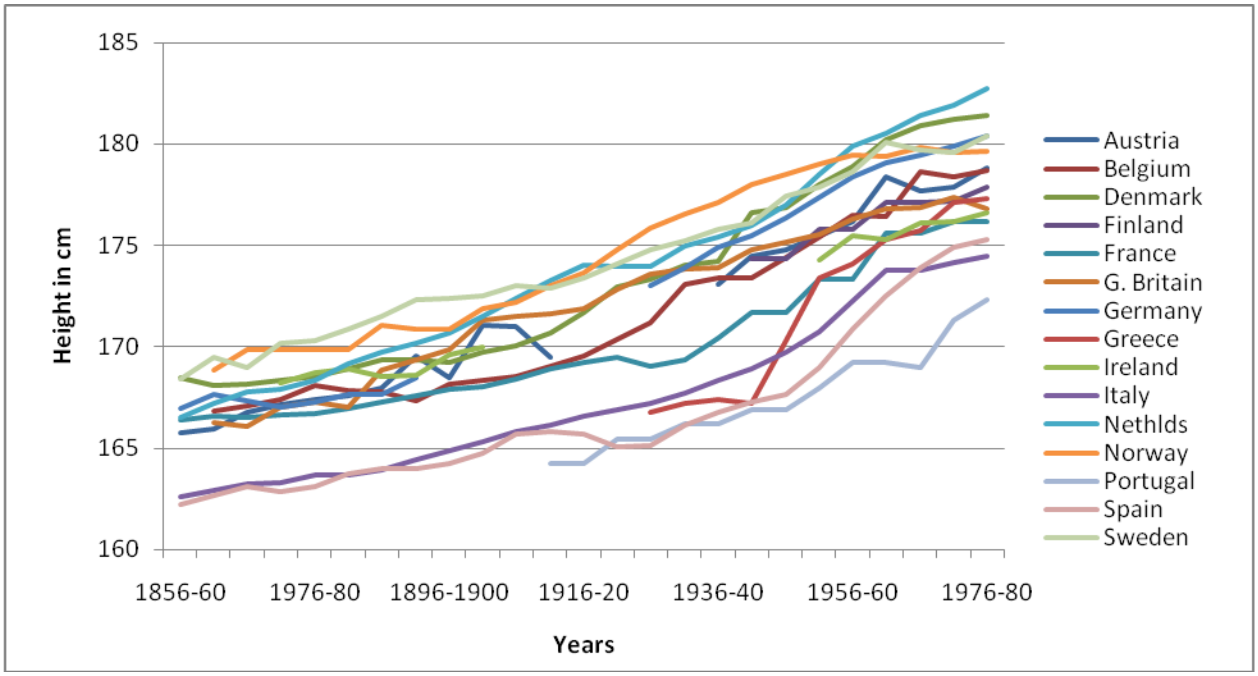

Figure 2: The Health Production Function

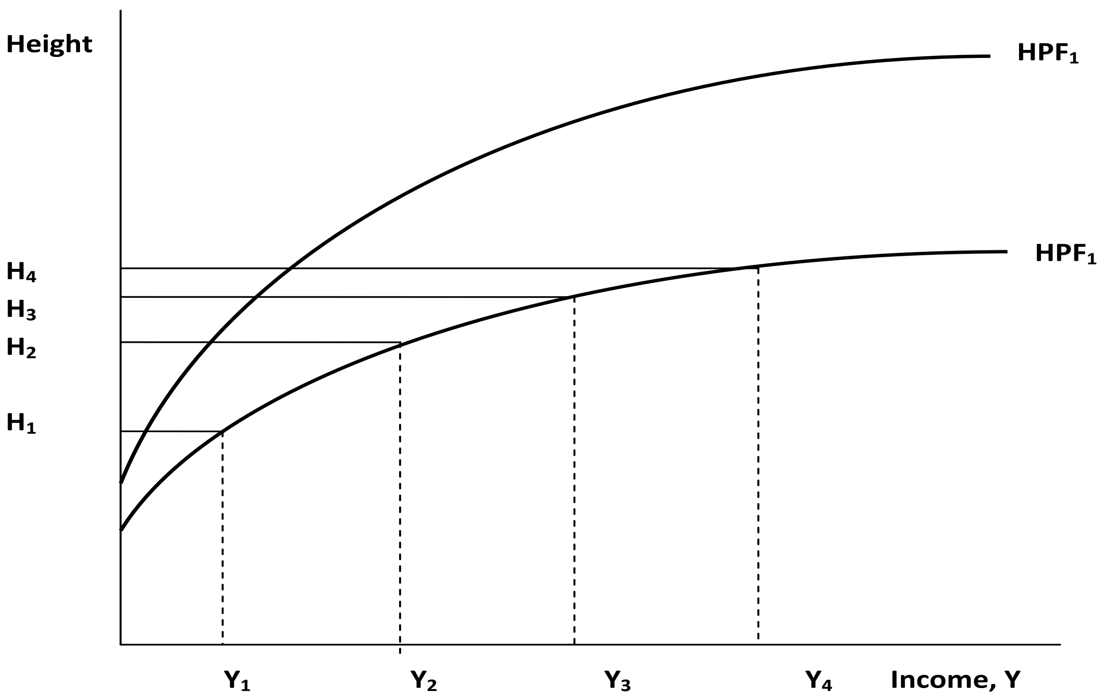

Figure 3: Infant Mortality Rates, 1856-60 to 1976-80