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THE HEIGHTS OF EUROPEANS SINCE 1750: A NEW SOURCE FOR EUROPEAN ECONOMIC HISTORY

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ABSTRACT

Economic and social historians have traditionally been concerned to measure changes in the income and welfare of populations in the past. Until recently, however, they have not recognized that anthropometric data, such as evidence on the average height achieved by a population at a particular age, provide sensitive indicators of the average nutritional status of that population. Records of conscription into the armies of eleven European countries betweeen 1761 and 1975 provide 144 observations of mean height. Using 64 observations, the paper explores the relationship between mean height and other indicators of health and welfare, in particular the level of GDP per capita and the level of infant mortality. Western European heights are shown to have responded systematically over the past hundred years to changes in income and disease, just as heights in the modern world respond to similar changes today. Average height is powerful evidence of the nature and extent of economic development.

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The Heights of Europeans since 1750: a new source for European Economic History *

European economic historians have been preoccupied, since the foundation of their academic discipline, with the study of the profound economic changes which have taken place in Europe during the past two hundred years. Recent studies in many countries have established the main outlines of those changes, the growth of manufacturing industry, the decline of agriculture, the increasing importance of foreign trade and the decline in the rates of growth of population, which occurred at various times in all European countries. Yet the effects which these changes have had on the people of those countries has remained curiously difficult to establish; the standard of living of the peoples of Europe has changed enormously during the transition from feudalism, but the exact delineation of that change has remained elusive.

In the past, the problem of measuring changes in the standard of living has been seen by historians as predominantly a problem of data collection. It was assumed that, once sufficient data on prices and wages had been collected, the measurement of real wages could follow; even if micro-economic data had been lost, methods such as national income analysis, combined with more accurate measurement of population changes, could provide a guide to movements in real incomes per capita. It is true that knowledge of the distribution of income is crucial to such analysis, but it can often be assumed or inferred from tax data or similar material. There are, in addition, many statistical difficulties, such as those of the choice of weights, the choice of base periods and the choice of the most appropriate analytical method, but there have been improvements in our knowledge of all these difficulties, so that they seem now either solved or capable of solution, at least at the levels of accuracy which are needed for studies of long-term historical processes.

It is probably inevitable that, at the time when so many of the problems which preoccupied earlier academic studies of the standard of living seem to be near to solution, economic historians should begin to feel dissatisfied with the measures which they have spent so long trying to make. This dissatisfaction was succinctly expressed some time ago, in a debate on the British standard of living, when Eric Hobsbawm wrote that "Man does not live by bread alone". (Hobsbawm 1963: 131). In other words, the traditional measures of real wages are inadequate to capture the enormous changes which have taken place in patterns of work and life during the past two centuries. At the least, measures of real wages need to be qualified by knowledge of changes in work intensity, of the impact of urban living and factory working and, perhaps most important, of the effect of all these changes on health and mortality. There is little point in an improvement in real wages which is bought at the expense of a miserable life and an early death. If historians ignore the existence of this trade-off during the period of industrialisation, by concentrating their attention only on the measurement of real wages, then they miss a fundamental part of the history of the working class. E.P.Thompson was right, therefore, to give equal emphasis to "Experiences" and to "Standards" in his discussion of this subject in The Making of the English Working Class (Thompson 1968)

As the mention of Hobsbawm and Thompson shows, (and many others could be cited) historians have not usually ignored the deficiencies of measures of real wages. Their problem has been that, if they wish to consider other life experiences as part of the standard of living, they have to be able to weigh up one experience against another, to judge whether an increase in real wages was brought at too high a price in misery, ill-health and increased mortality. This is difficult to do; whatever the utility maximising theorists of neo-classical economics may assume, few of us are confident about such calculations in our own lives, and it is far more difficult to make such judgements about millions of people in the past. Recent attempts to do so by J.G. Williamson (Williamson 1981, 1982), though innovative and imaginative, rest on evidence which is too poor to be persuasive.

What is needed, in fact, is a measure which will in some way sum up all the facets of experience which make up our standard of living, or will do so for substantially more of them than are summed up in measures of real wages. This article is devoted to a discussion, in the context of European economic history, of one possible measure, the changes in the heights of Europeans since the middle of the eighteenth century.

Auxology and history

Historians are unfamiliar with the idea that measurements of height and of other aspects of human physique are of any relevance to the measurement of standards of living. Some early work of Emmanuel le Roy Ladurie and others in this field was sceptically received and was not followed up or emulated. (Aron *et al*. 1972) By contrast, human biologists and physical anthropologists have long believed that growth in humans is responsive to changes in the environment. An early pioneer in the measurement of human growth was Adolphe Quetelet (1796-1874), a Belgian whose work was widely known throughout Europe and who, at the same time as L.R. Villermé in France, surveyed the growth of children and adolescents and sought to describe and explain its principal features. The work of Quetelet and Villermé stimulated Edwin Chadwick, in England, to organise surveys of the heights of children in factory districts in the 1830s. Since that time, the study of human growth or 'auxology' has become a scientific discipline in its own right and has given rise to numerous surveys of growth throughout the world. (Tanner 1981; Eveleth and Tanner 1976).

These studies are based on the belief, now well established, that

> "A child's growth rate reflects, better than any other single index, his state of health and nutrition; and often indeed his psychological situation also. Similarly, the average value of children's heights and weights reflect accurately the state of a nation's public health and the

> average nutritional status of its citizens, when appropriate allowance is made for differences, if any, in genetic potential. This is especially so in developing and disintegrating countries. Thus a well-designed growth study is a powerful tool with which to monitor the health of a population, or to pinpoint subgroups of a population whose share in economic and social benefits is less than it might be." (Eveleth and Tanner 1976:1)

It is for this reason that the World Health Organisation and other bodies make use of measurements of growth to assess the efficacy of health and development programmes in the world today.

Growth measures, as Eveleth and Tanner say indicate the 'average nutritional status' of those measured. That is, human growth reflects not only the input of nutrients in the form of food and drink, but also the demands which the growing child and adolescent places on his body. Nutrition is required for body maintenance, for work or other physical activity and for growth; if the nutrition is inadequate to sustain the body in a healthy state, or if the demands of work are excessive, growth will be retarded or, in the extreme case, will cease altogether. In addition, disease can place extra demands on the body for additional nutrients; if these are not forthcoming, growth will again be affected. 'Nutritional status' is thus a net rather than a gross measure of nutrition; it measures not what the human body takes in (as in studies of diet which are familiar to many historians) but what the body makes of those nutrients when combined with other pressures and requirements.

The pattern of growth in childhood and adolescence is common to all human populations. Growth is most rapid in infancy, slows down during childhood and then increases in speed during puberty or the 'adolescent growth spurt' before slowing again until final height is achieved in the late teenage years. This growth pattern can be seen clearly both in historical series such as those compiled by Quetelet, in modern studies of the under-developed world and in modern studies of the developed world; the timing of particular events, such as the adolescent growth spurt or the achievement of final heights, varies between different genetic groups within the world population, but the overall pattern is common to all.

Within particular genetic groups, such as the white European populations, variations in nutritional status produce variations in the timing of growth, and the extent and nature of such variations from the pattern and timing found in a well-nourished population give a guide to the nature and severity of mal-nutrition (in the widest sense of an imbalance between nutrient intake and the needs of the body). Since a frequency distribution of heights at a given age corresponds very closely to the normal or Gaussian distribution, and since the standard deviation of such a distribution is standard in adolescence and adulthood at about 6.4 cm., it is conventional to describe the mean heights of other populations as falling, for example, between the 3rd and 5th centile of the current British height distribution. Such a description means that the mean height of a given population is lower than the heights of all but 95 per cent of the current British population, but higher than that of 3 per cent of that population.

An episode of malnutrition, such as a famine, can delay growth and therefore cause the curve of growth of a malnourished population to deviate from that of a well-nourished population. If the malnutrition is short-lived, however, it is likely that children and adolescents will resume growth once the episode is passed; they may even grow faster, in a phenomenon known to auxologists as 'catch-up' growth and thereby achieve final heights similar to those which they would have achieved had the famine not taken place. This phenomenon was observed, for example, in the aftermath of the Dutch 'hunger winter' of 1944. (Stein et al. 1975) If the malnutrition is prolonged, perhaps beginning at the foetal stage and affecting both childhood and adolescence, then growth will typically be slower than for a well-nourished population and the final height which is achieved may well be consequently less.

This emphasis on the environmental or nutritional causes of variation in growth may seem to be at odds with the common emphasis on genetic causes of variations in heights and other bodily characteristics. There is no doubt that the overall pattern of growth is genetically determined, nor that a substantial part of an individual's growth is inherited from parents, but there is also substantial evidence that most of the variation of average heights of populations within very large ethnic groups, and certainly most of the variation of the average heights of sub-groups within those populations, is determined by environmental rather than genetic factors. Two signs of this are that "the mean heights of well-fed West Europeans, North American whites and North American blacks are nearly identical" (Fogel et al. 1982: 405) and that in all western European societies (with the recent exception of Sweden) social class is closely correlated with average height. A further indication of the importance of environmental influences on average height is that in the world today there is a very strong correlation between average height and per capita national income (Steckel 1983).

At the same time, the importance of genetic factors and the nature of their interaction with environmental and socio-economic factors should not be underestimated. As Eveleth and Tanner put it:

> "Such interaction may be complex. Two genotypes which produce the same adult heights under optimal environmental circumstances may produce different heights under circumstances of privation. Thus two children who would be the same height in a well-off community may not only both be smaller under poor economic conditions, but one may be significantly smaller than the other ..."
> (Eveleth and Tanner 1976:222)

Interactions of this kind are still not well understood. Nor is the relationship between the tempo of growth and the final height which is achieved. As Tanner puts it:

> "...within a given, well-nourished population, there is no correlation between tempo and final height: tall men are as likely to have been late as to have been early maturers. Even between populations at different levels of nutrition, the correlation is far from close. A population which is short at age

> 14 may be so either because its children are delayed in growth (in which case they may reach a considerable height as adults) or because they are simply short -- before, then and later with average tempo. As for trends within a single population, in historical data increasing mature size usually is accompanied by increasing tempo of growth. But the two should certainly not be regarded as inseparable ....." (Tanner 1982:575)

This difficulty makes it important for auxologists to examine, so far as possible, the whole pattern of growth of a population, rather than simply the average height achieved at one particular age.

Even though there remain many puzzles connected with human growth, the outlines of the process of growth and its connections with environmental influences are clear. Growth is a measure of nutritional status, of the synergistic relationship between nutritional intake, work effort, and health. Malnourished and unhealthy populations are short populations, well-fed and healthy populations are tall populations. This fact is of enormous importance to historians, because it means that growth statistics offer a way of summing up many of the different influences on human existence which we think of when we speak of the standard of living. Growth statistics are more comprehensive than measures of real wages for the discussion of the standard of living within individual societies and they are also a means of comparing standards of living between different societies within the same genetic group. In the light of this modern knowledge, it is interesting that Karl Marx, presumably aware of the work of Quetelet, Villermé and Chadwick, used height statistics in his discussion of the impact of industrialisation. He referred in Capital to J. von Liebig's description of the declining health of the French and German populations as shown by the condition and height of their military recruits and argued that this decline in England had made factory legislation necessary:

> "The limiting of factory labour was dictated by the same necessity which spread guano over the English fields. The same blind eagerness for plunder that in the one case exhausted the soil, had, in the other, torn up by the roots the living force of the nation. Periodical epidemics speak on this point as clearly as the diminishing military standard in Germany and France." (Marx, 1867; 1961: vol 1, 239)

The Evidence

Marx draws our attention to the principal source of evidence for the study of human heights in Europe over the past two centuries. Records of military recruitment, which survive in vast quantity, typically contain information on the height of the recruit. This information appears to have been collected and recorded for two main reasons. First, it was common from the eighteenth century onward to require that a recruit should be taller than some defined standard of height. As Tanner puts it:

> "Tall soldiers were preferable to short ones. Not only were they generally stronger; they could cover

> more ground on the march because of a greater length of stride, and in combat they could reach further with the bayonet and load more easily the long-barrelled muskets of the time, in which the charge had to be rammed down the muzzle. The custom of having troops march in step, introduced about 1700 in Prussia, set a limit to permissible differences in height; and the requirements of ceremonial .....demanded a specialised corps whose heights had a still smaller range." (Tanner 1981:98)

Potential recruits were, therefore, measured to make sure that they could pass the height standard. The second reason for measurement, and the reason why the measurement was recorded along with other details of the recruit, was to enable him to be identified, a particularly important need in an age when desertion was frequent and when, as in England, recruits were known to join and desert in order to obtain the "King's shilling" several times over.

For these reasons, heights of recruits were recorded as early as the first half of the eighteenth century, in Norway from 1741, and soon afterwards in England from 1755 and in Sweden from 1767. Other countries followed as conscription and the growth of standing armies increased the bureaucratisation of military affairs. Conscription brought with it, in addition, a new development, for it was common for conscription to be based on the inspection of very large sections, if not the whole, of the young male population on a regular basis. This practice gives rise to the survival, to our own day, of records of heights and other physical and social characteristics, such as occupation and place of birth or residence, for entire populations of young men.

The records of different European armed forces exist in many different forms and information survives in them about the heights of many millions of soldiers. Table 1 presents in summary form the results of investigation of these records by human biologists and historians, together with some information from modern periods drawn from sample surveys of the stated population. It is not possible, unfortunately, to be entirely certain that the results are strictly comparable one with another, since military recruiting practices varied from time to time and from place to place. In some countries, for example, conscription gave rise to measurements of the entire male population at a particular age; in others, only those young males who were actually selected for military service were recorded. In some, volunteer armies were the norm and the records of heights stem, therefore, from a self-selected sample which may not be representative of the male population. It is unlikely, however, that these differences in the nature of the statistics are large enough to vitiate comparisons over time and between the countries listed in the table.

Interpretation of Table 1 requires some attention to the pattern of human growth which was discussed above. Since both the speed of growth and the absolute height achieved at a particular age can vary between populations and between different time periods, it is necessary to adopt a common standard against which to set measurements of height which were conducted at different ages. In the 5th column of table 1, therefore, the absolute average heights in cm. are accompanied by a measure of their relationship to the modern English standard. Each average height is expressed as an approximation to the quintiles of the English standard for the age at which measurements took place or, in the case of men measured older than 18, the quintiles of the modern British population of 18 year old males. (In a few cases, with very short populations, the 3rd percentile is also used.) In the section for Belgium, for example, the figure '10' in column 5 against the measurements of Houze for 1880-82 shows that Belgian males of 19-25 at that time had a mean height greater than that of 5 per cent of modern British males aged 18 but less than that of 90 per cent. Later in that table, the measurement of Twiesselmann suggests that Belgians in 1969 had a mean height greater than that of 45 per cent, but less than that of 50 per cent, of modern British males; that is, by 1969 the Belgian and the British populations were very close in stature. The mean height of 20-year old Italians in 1874-6 was less than the height of all but 97 per cent of the modern British, while, at the other extreme, the mean height of 18-year old Dutch males in 1975 was greater than the height of all but 20 per cent of the modern British population.

<u>Analysis</u>

Table 1 and Figure 2 show the very large changes which have taken place during the past one hundred and fifty years in the average heights of Western European populations. Why did these changes occur?

Human biologists, from Villermé onwards, have consistently emphasised the importance of the environment in promoting or retarding human physical growth. They have devoted a great deal of attention to the effects of malnutrition and other forms of deprivation on individual health and growth and, in their studies, have demonstrated how improved nutrition and control of disease can produce immediate and dramatic effects on the growth of children. (Martorell and Klein 1980). At the level of whole populations rather than individuals, human biologists have also shown that in almost all countries in the modern world - an exception is Sweden - different social classes have different average heights. In Britain, for example, class differences in heights can be perceived in groups of infants as early as the age of two, while the differences are even more pronounced in adolescence. (Smith _et al_. 1980). Within countries, therefore height is correlated with that complex of factors which goes to make up social class while, between countries, it is a matter of casual observation - reinforced by a study of Eveleth and Tanner's _Worldwide Variation in Human Growth_ (1976) - that the richer countries in the world tend to be the countries with the taller populations.

Economists and historians have been slow to understand the potential of this body of scientific knowledge for their own disciplines. The clear implication of the study of human biology is that human height responds to, and is a sensitive measure of, differences in the standard of living of human populations from one time to another, from one place to another and from one social class to another. Changing height is, in other words, a function of economic and social change. Since this is so, historians and economists should seek to use measures of height in their description of the economic and social development of nations and should also try to understand more fully the exact relationship between height and social and economic factors.

A start has recently been made in the use and explanation of evidence about changes in human height. A group of economists and historians from Britain and the United States, working under the leadership of Robert Fogel of the University of Chicago, have studied data from Britain, from the British West Indies and from the American colonies and the United States. The first results of these studies have recently appeared in a special issue of Social Science History and provide a number of striking findings: there appears, for example, to have been very little difference between the average adult height of white American-born males at the time of the American Revolutionary War, during the American Civil War and at the time of the second World War, although average heights probably both rose and fell between those dates; rises and falls over time occurred in the heights of poor children in London between 1770 and 1870, with a very marked rise in average heights at the end of the Napoleonic wars; at the individual level, tall slaves in Trinidad between 1810 and 1820 had a significantly reduced chance of death compared to shorter slaves. (Sokoloff and Villaflor 1982; Floud and Wachter 1982; Friedman 1982). These studies are continuing with the collection of very large amounts of data about the heights of military recruits in Britain and the United States, which will make it possible to describe changes in heights in those countries from the middle of the eighteenth century until the present day.

In an associated study, Steckel has sought to explore the nature of the relationship between social and eoonomic factors and height, by studying the range of height which is observable in the modern world. (Steckel 1983) He has drawn on the work of human biologists to provide 163 examples of average adolescent heights from different societies in the modern world, together with 30 examples of average adult heights, and has tried to explain the variation in those heights by reference to the per capita income of the countries from which the height data were derived, and to a number of other measureable factors which may have a bearing on height differences. These include the extent of income inequality, the racial composition of the populations and the extent of urbanisation. Steckel found that there was a very strong correlation between the average height of a population and the logarithm of per capita income of the economy from which the population was taken, and that the addition of information on income inequality within the society made the statistical relationship between height and these social or economic factors even stronger.

Steckel warns in his article that there is no reason to believe that the relationship between height and its socio-economic determinants should remain steady over long periods of time:

> "Improved medical technology probably shifted the relationship between average height and per capita income. Knowledge of the germ theory of disease, for example, enabled individuals to improve health, and therefore increase height, with no change in income."

(Steckel 1983:4-5)

Nevertheless, Steckel's results provide a stimulus to investigate whether similar relationships between height and socio-economic factors existed in the past, even if the relative effect of different factors differed from those which can be observed today.

It is agreed by human biologists that income is a primary determinant of height, while Steckel's work suggests that the distribution of the national income can also affect the average height of that nation. It is also agreed that disease can have substantial effects on individual and population average heights. This knowledge makes it sensible to investigate whether the changes in European heights which have occurred in the past, and the differences between European nations, can be explained by reference to the incomes and disease patterns of those nations. Such an investigation can only be carried out for the relatively recent past, since adequate information on national income per capita and on mortality - which must stand in place of information on health - are available only from about 1880 onwards in most western European countries. Nevertheless, the information on heights in table 1 can be matched, in 64 cases, with information on gross domestic product per capita and on the level of infant mortality in the country and at the time concerned. No information on the level of inequality of incomes is available for most countries, so Steckel's analysis cannot be repeated in this respect with historical data.

The relationship between height and these socio-economic factors has therefore been investigated, for those 64 cases, by regression analysis. The results are given in table 2, and the notes to the table give greater information on the sources of the data which were used. The results show that both the level of infant mortality and the level of gross domestic product per capita have exerted a strong influence on European heights. Indeed, taken together with the other variables in the regression equation, these factors explain about 96 per cent of the observed variation in heights between and within western European populations since 1880. If one takes each variable separately, (assuming that the other variables are held constant) then the results show that an increase of one U.S. dollar (at constant 1970 prices) in G.D.P. per capita has been accompanied by an increase in the average height of the population by 0.003 cm; a decrease of one death per thousand live births has been accompanied by an increase in average height of 0.020 cm.

The results also show that there have been systematic differences between different European populations. The regression equation has been designed so that the base for comparison between populations is the experience of Italy; the intercept in the regression results reflects the level of height in the Italian population before World War I from which factors such as GDP per capita would raise and infant mortality levels would lower, Italian heights. So-called 'dummy variables' are employed in the regression analysis to discover whether the experience of other countries differed from that of Italy. The results show that, for some reason, Norway, Sweden, the Netherlands and Denmark were significantly (in a statistical sense) different from Italy;

they had taller populations at given levels of GDP per capita and infant mortality than did Italy, whereas Belgium, France, and Switzerland showed no significant difference from the Italian experience.

Dummy variables were also employed to discover whether the nature of the relationship between height and GDP per capita, infant mortality and national factors changed over the course of time. The fact that dummy variables for the inter-war and post-war periods have no statistical significance demonstrates that there was no change between periods in that relationship.

The stability of the relationship between height and per capita income can also be tested by comparing Steckel's results with those in table 2. The comparison cannot be exact, since the explanatory variables used are different, but it is possible to compare the effect of national income or gross domestic product per capita on height, while holding all the other influences on height constant. This is done in table 3 which shows a very close correspondence between the heights which would be predicted on the basis of different levels of income, if Steckel's equation and that for the European heights were each taken as a complete description of the determinants of height. This close correspondence suggests that there have been no major changes over time in the relationship between height and income and that Steckel was too cautious.

This analysis of the determinants or correlates of European height raises many questions of interpretation. As is almost always true, neither the dependent variable in the equation, height, nor the independent variables are measuring quite what they are supposed to measure. The difficulty with the measures of height is that a substantial number of them may not be of final adult heights. In modern Britain, and probably in most western European countries, the average height of the male population aged 17.5 is approximately 98 per cent of the average adult height. (Tanner 1978:19) This reflects the tempo of growth of modern, well-nourished children and implies that virtually all growth in the population average has ceased by the age of 19 or 20. Tanner has noted, however, that

> "..... in historical data increasing mature size usually is accompanied by increasing tempo of growth. But the two should certainly not be regarded as inseparable ......" (Tanner 1982:575)

Evidence from British sources shows that it is likely that the lower heights in table 1,drawn from earlier periods or from populations with lower incomes, were the product of a slower growth than is normal today. (Floud and Wachter 1982) If that is so, then some of the measurements of the average heights of 19 or 20 year olds in table 1 are somewhat lower than mature heights, since significant growth - at least 1 or 2 per cent of final height - might still occur. In other words, the different average heights in table 1 may not be strictly comparable,as they should be in the statistical analysis.

This difficulty is formally insuperable, since so many of the data relate to army conscripts where measurements were taken at one age and where, therefore, very little if any information is available for other ages. However, it may not be very serious in practice. First, modern studies of malnourished populations suggest that it is unlikely that the tempo of growth would have been delayed by more than two years; 98 per cent of final height would therefore have been reached at the latest at the age of 19.5. This implies that, for almost all the cases in table 1, the measurement must be within two per cent of final height. While this is not an insignificant amount - two per cent of 165 cm, for example, is 3.3 cm. - it is small in comparison with change in heights which has occurred in most countries. It is therefore unlikely that the results of the regression analysis would be seriously disturbed by correcting for tempo, impossible as this would be in practice. Second, as Tanner points out, tempo of growth and mature final size are to a considerable extent independent of each other, even for population data; both are thought to be responsive to nutritional change, though which nutritional change affects which outcome is still unknown. Since they are largely independent of each other and responsive to nutrition, the fact that some of the measurements in table 1 relate to populations who had not yet reached mature height does not matter, since delayed attainment of final height is an indication of a nutritional state less good than that of modern Europe.

The independent variables in the equation, income and disease, are also less well measured by the data which are available than they should be. Steckel's results suggest very strongly that per capita gross domestic product is an inadequate measure of income, since he found that the distribution of income is important in explaining height in the modern world. In addition, infant mortality is an inadequate measure of the disease environment, since modern evidence shows that diseases of childhood and adolescence affect growth in populations which have survived the period of infancy.

The effect of omitted variables, such as income inequality, or of inadequately measured variables, such as health or disease, may be reflected in the regression analysis, at least in part, by the dummy variables which represent systematic differences between countries. If, for example, Norway, Sweden, the Netherlands and Denmark had systematically lower levels of income inequality, or if those areas had a different disease environment, perhaps for climatic reasons, then that might explain their taller populations. Another possibility, which will be explored in future analyses of this material, is that these differences between countries reflect differences in the age at which recruits were measured. However, table 1 shows that only in Denmark were recruits significantly older on average than in Italy, so it is unlikely that this possibility will explain more than a part of the height differences between countries. The issue deserves more study and the collection of more relevant data.

There remain two more technical points. First, Steckel suggests that there is a circularity in regarding adult height as being determined by average income, since if adult males are healthier and stronger they will produce more and thus increase income. This difficulty can be circumvented in a statistical sense by using a different regression method, that of two-stage least squares, and Steckel's results are based on that method. However, it is doubtful whether enough additional data on the determinants of income are available, in historical periods, to make this method work; Steckel also found that "The results for adults are not sensitive to the method of estimation" (Steckel 1983: 7, n. 32) and it therefore seems unlikely that the results for European heights would be significantly changed if a different method were used.

Second, there is a high correlation between gross domestic product per capita and the level of infant mortality, for obvious reasons. This "multicollinearity in the independent variables", as it is known in statistical parlance, should not affect the level of the coefficients reported in table 2, nor the strength of the overall correlation between height and its supposed determinants, but it might affect the accuracy of predictions such as those shown in table 3. However, prediction of this kind outside the range of the data - for example to earlier periods - is fraught with other difficulties; the extent of multicollinearity is therefore merely an additional reason for care. Once again, it would be desirable to see whether the addition of more data would change the conclusions, as it might do if multicollinearity were a serious problem.

Despite these difficulties and cautions, the results of the regression analysis are striking. Western European heights have responded entirely systematically, over the past hundred years, to changes in income and disease, just as heights in the modern world respond to similar differences between countries. Economic development and the control of disease have altered the bodies of the people of Europe.

Conclusion

The analysis in this article has been conducted entirely with data drawn from national populations. However, the literature of human biology suggests very strongly that similar methods of analysis could be employed to elucidate differences in the rate of economic development within nations, for example between one class and another or between one area of the nation and another. In the nineteenth century it was commonly thought that rural populations were taller and stronger than urban populations, while today the reverse is the case. Moreover, class differentials in height have almost certainly narrowed over the course of time. If it is possible for historians and economists to collect, in many countries, evidence on height changes specific to particular classes, occupations and regions, then they have a powerful new method for the description and analysis of the nature and extent of economic development. Research of this kind is now being conducted in Britain and in the United States; the analysis of western European heights in this article is only a beginning which, I hope, will soon be superseded by more detailed study of the history of European heights.

TABLE 1 The mean height of western European male populations

Country[1]	1 Date	2 Age of men measured	3 Mean height cm.	4 Quintile of British standard (see text)	5 Source[2]
A. <u>Belgium</u>	1834	17	164.0	<10	Quetelet
	1880-82	19-25	165.5*	<10	Houze +
	1902-4	20	165.8*	<10	Vervaeck +
	1920	19-20	166.0*	<10	Ann. Stat. +
	1926	19-20	167.0*	<15	Govaerts and Sillevaerts +
	1932	19-20	167.5*	<15	Ann. Stat. +
	1938	19-20	168.2*	<20	Ann. Stat. +
	1947	19-20	169.8	<25	Martin +
	1953	19-20	171.7*	<35	Martin +
	1969	18±	173.9*	<50	Twiesselmann +
B. <u>Denmark</u>	1789[3]	22	165.7	<10	Johansen
	1815[4]	22	165.4	<10	"
	1825[4]	22	167.0	<15	"
	1835[4]	22	166.5	<15	"
	1845[4]	22	166.5	<15	"
	1846[5]	22	167.2	<15	"
	1852-56	22	165.3	<10	"
	1880-89	22	167.3*	<15	"
	1879-88	18-25	167.7	<15	Mackeprang +
	1890-99	22	167.8*	<15	Johansen
	1891-1900	18-25	168.4	<20	Mackeprang +
	1904-5	18-25	169.1*	<20	"
	1911-20	22	169.1*	<20	Johansen
	1913	20	169.5	<25	Heiborg +
	1921-30	20	169.6*	<25	Johansen
	1930	20	169.9	<25	Kiil +
	1931-40	20	171.0*	<30	Johansen
	1945	20	174.4	<50	Ann. Stat. +
	1941-50	20	173.5	<45	Johansen
	1950	20	173.9*	<50	Ann. Stat. +
	1960	19	175.4*	<55	"
	1966-75	19±	177.5*	<70	Johansen
	1968[6]	17±	175.0	<55	Andersen
C. <u>France</u>	1819-26[7]	20	166.0	<10	Aron, Dumont, & Ladurie
	1880	20	165.4*	<10	Chamla
	1890	20	165.4*	<10	"
	1900	20	165.8*	<10	"
	1910	20	166.4*	<15	"
	1920	20	165.7*	<15	"
	1930	20	167.4*	<15	"
	1940	20	168.5*	<20	"
	1950	20	168.3*	<20	"
	1960	20	170.0*	<25	"
	1971[8]	17±	173.3	<45	Sempé *et al*.

TABLE 1 continued

D. Germany	1	2	3	4	5
(i) All Germany	1936	20	169.6	<25	Müller +
	1959	20	173.2	<45	Harbeck +
(ii) North Germany	1889[9]	20-22	167.7	<15	Meisner +
	1889[10]	20-22	169.2	<25	"
	1934[11]	20	173.6	<45	Büsing +
	1961[12]	20	173.7	<45	Finger & Harbeck
	1962[13]	18±	176.3	<60	City of Hamburg
(iii) West Germany	1887-94[14]	20	165.2	<10	Ammon +
	1938[14]	19-22	168.9	<20	Schaeble +
	1958[15]	20	173.5	<20	Finger & Harbeck +
(iv) Bavaria	1875	conscripts	164.6	<10	Ranke +
	1896	20	166.6	<15	Fürst +
	1900	20	166.8	<20	Fürst +
	1910	20	166.8	<20	Fürst +
	1923[16]	20-34	169.2	<25	Bach +
	1935	20	168.5	<20	Fürst +
	1958	20	171	<30	Finger & Harbeck +
E. Italy					
(i) All Italy	1874-6	20	162.2	<3	Svimez
	1880	20	162.8*	<5	Cappieri +
	1890	20	163.2*	<5	Cappieri +
	1894	20	163.8	<10	Svimez
	1900	20	163.8*	<10	Cappieri +
	1910	20	163.9*	<10	Cappieri +
	1920	20	162.5*	<5	Cappieri +
	1928	20	164.4	<15	Svimez
	1930	20	165.5*	<10	Cappieri +
	1938	20	166.2	<10	Svimez
	1940	20	166.0*	<10	Cappieri +
	1948	20	167.0	<15	Svimez
	1952	20	167.4*	<15	Cappieri +
(ii) North Italy	1874-6	20	163.6	<5	Svimez
	1894	20	165.0	<10	"
	1928	20	165.8	<15	"
	1938	20	167.7	<15	"
	1948	20	168.7	<20	"
	1965-6[17]	18±	172.0	<35	de Toni
	1969[18]	18±	173.8	<45	Vizzoni & Barghini
(iii) South Italy	1874-6	20	163.6	<5	Svimez
	1894	20	165.0	<10	"
	1928	20	165.8	<15	"
	1938	20	164.0	<10	"
	1948	20	164.3	<10	"
	1970[19]	18±	174.0	<50	Tatofiore

TABLE 1 continued

	1	2	3	4	5
F. Netherlands	1865	19	165.0	<10	Van Wieringen
	1877-82	19	165.2	<10	Bruisma +
	1887-92	19	166.4	<15	Bruisma +
	1907	18.5	169.0*	<20	Bolk +
	1917	19	170.0*	<25	Van Wieringen
	1920	18.5	170.0*	<25	Ann. Stat. +
	1930	18.5	172.0*	<35	"
	1940	18.5	173.0*	<40	"
	1950	18.5	174.0*	<50	"
	1950	18	174.1	<50	Van Wieringen
	1955	18.5	175.0*	<55	Ann. Stat. +
	1955	18	175.3	<55	Van Wieringen
	1960	18.5	176.0*	<60	Ann. Stat. +
	1960	18	176.0	<60	Van Wieringen
	1965	18	177.4*	<70	"
	1970	18	178.7*	<75	"
	1971	18±	177.6	<70	"
	1975	18	180.1	<80	"
G. Norway	1761	18.5	159.5	<3	Kiil
	1855	22	168.6	<20	Kiil
	1880	22	169.0*	<20	Kiil +
	1890	22	169.6*	<25	Kiil +
	1900	22	170.4*	<30	Kiil +
	1910	22	171.1*	<30	Kiil +
	1920	20	171.4*	<30	Kiil +
	1920[20]	18	173.6	<45	Schiötz
	1930	20	172.8*	<40	Kiil +
	1937	20	173.8*	<45	Ann. Stat. +
	1956	20	176.9*	<65	"
	1960	20	177.1*	<65	Ann. Stat. +
	1960[20]	18	179.3	<80	Baklund and Wøien
	1962[20]	18±	179.3	<80	Iversen
H. Portugal	1899	20-21	163.4	<5	Fontesa Curdoso +
	1911	'soldiers'	163.5	<5	Tamagnini +
I. Spain	1860-1893	19-22	163.7	<5	Oloriz +
	1903-1906	'soldiers'	163.0	<5	Sanchez Fernandez +
	1955	'soldiers'	166.1	<10	Hernandez Grimenez +
J. Sweden	1840	21	165.08	<10	Hultkrantz
	1880	20	168.6*	<20	Lundman +
	1883	18±	168.5	<20	Ljung
	1890	20	169.4*	<25	Lundman +
	1900	20	170.3*	<30	"
	1910	20	171.7*	<35	"
	1920	20	172.7*	<40	"
	1930	20	173.6*	<45	"
	1938-9	18±	177.5	<65	Ljung
	1939	20	174.4*	<50	Lundman +
	1949	19	175.0*	<55	"
	1961	18	177.0*	<65	"
	1974	17±	178.4	<75	Ljung

TABLE 1 continued

	1	2	3	4	5
K. Switzerland	1884-6	19	163.5	< 5	Pittard +
	1908-10	19	165.9	< 10	Pittard +
	1927-32	19	168.5	< 20	Schlagin haufen +
	1947	19	170.9	< 30	Ann. Stat. +
	1952	19	171.3*	< 35	"
	1957	19	172.1*	< 35	"
	1958-64[21]	18±	176.0	< 60	Heimendinger

Notes to Table 1

1 Unless otherwise noted below, measurements relate to the whole country.

2 A considerable number of measurements in this table are reported by and taken from Chamla (1964). These are marked +. Interpretation of these and other measurements is mine.

3 Rovso, E. Jutland only.
4 North Sealand only.
5 Funen only.
6 Copenhagen only.
7 Calculated as the unweighted grand mean of 86 departmental means.
8 Paris only.
9 Holstein only.
10 Schleswig only.
11 Kiel only.
12 Schleswig-Holstein only.
13 Hamburg only.
14 Baden only.
15 Baden, Palatinate, Hesse, Rheinland only.
16 Munich only.
17 Genoa only.
18 Carrara only.
19 Naples only.
20 Oslo only.
21 Basel only.

* Measurement used in regression analysis: see table 2.

TABLE 2 The determinants of European heights, 1880-1971

Independent Variables	Coeff	t value
Intercept	165.438	229.073
INFM	- 0.020	- 5.335
GDPPC	0.003	11.050
CD5 (Norway)	5.018	13.449
CD6 (Sweden)	4.880	14.191
CD4 (Netherlands)	4.507	15.140
CD2 (Denmark)	3.008	9.685
CD1 (Belgium)	Not significant at 5% level	
CD3 (France)	Not significant at 5% level	
CD7 (Switzerland)	Not significant at 5% level	
TD1 (1920-1945)	Not significant at 5% level	
TD2 (1946-1971)	Not significant at 5% level	

N = 64

$\bar{R}^2$ = 0.964

Method OLS, pooled cross-section and time-series data.
Omitted variables : Italy and Time period 1880-1919.

Definition and source of variables

Dependent variable: Height in centimetres. Statistics for average height were obtained from a large number of secondary sources. Details are in table 1.

Independent variables: GDP per capita in constant 1970 US dollars. Calculated from Tables A1, A7-8 and B2-4 of A. Maddison Phases of Capitalist Development (Oxford U.P. 1982).

INFM: deaths of infants under one year old per 1000 live births, from Table B7 of B.R. Mitchell European Historical Statistics 1750-1970 (Macmillan 1975)

Note: Both infant mortality and GDP per capita relate to the year in which the height observations were made. Further investigation is required to establish the possible lags, since a regression of height on these variables measured 20 years before the height observation gave a slightly worse fit.

TABLE 3 The relationship between height and per capita income in historical and contemporary data. Adult males.

Hypothetical income per capita	Predicted height in cm. on basis of		
	Steckel	Floud 1	Floud 2
(1)	(2)	(3)	(4)
150	160-9	Out of range	
250	162.7	Out of range	
500	165.1	165.0	163.8
1000	167.5	166.4	166.9
2000	169.9	169.0	169.9
3000	171.4	171.6	171.7
4000	172.4	174.2	173.0
5000	173.1	Out of range	

<u>Notes</u>

Column 2 From Steckel, Table 3. The prediction is based on a national study for a population with European ancestors; the Gini coefficient is evaluated at the sample mean. Based on the log (base e) of per capita income.

Column 3 Calculated from Table 1, assuming a national study for a European population (Italy); INFM is evaluated at the sample mean.

Column 4 Calculated from a regression model similar to that in table 1, but using the log (base e) of GDP per capita as the predictor. $\bar{R}^2 = .96$. Assuming a national study for a European population (Italy), INFM is evaluated at the sample mean.

FIGURE 1

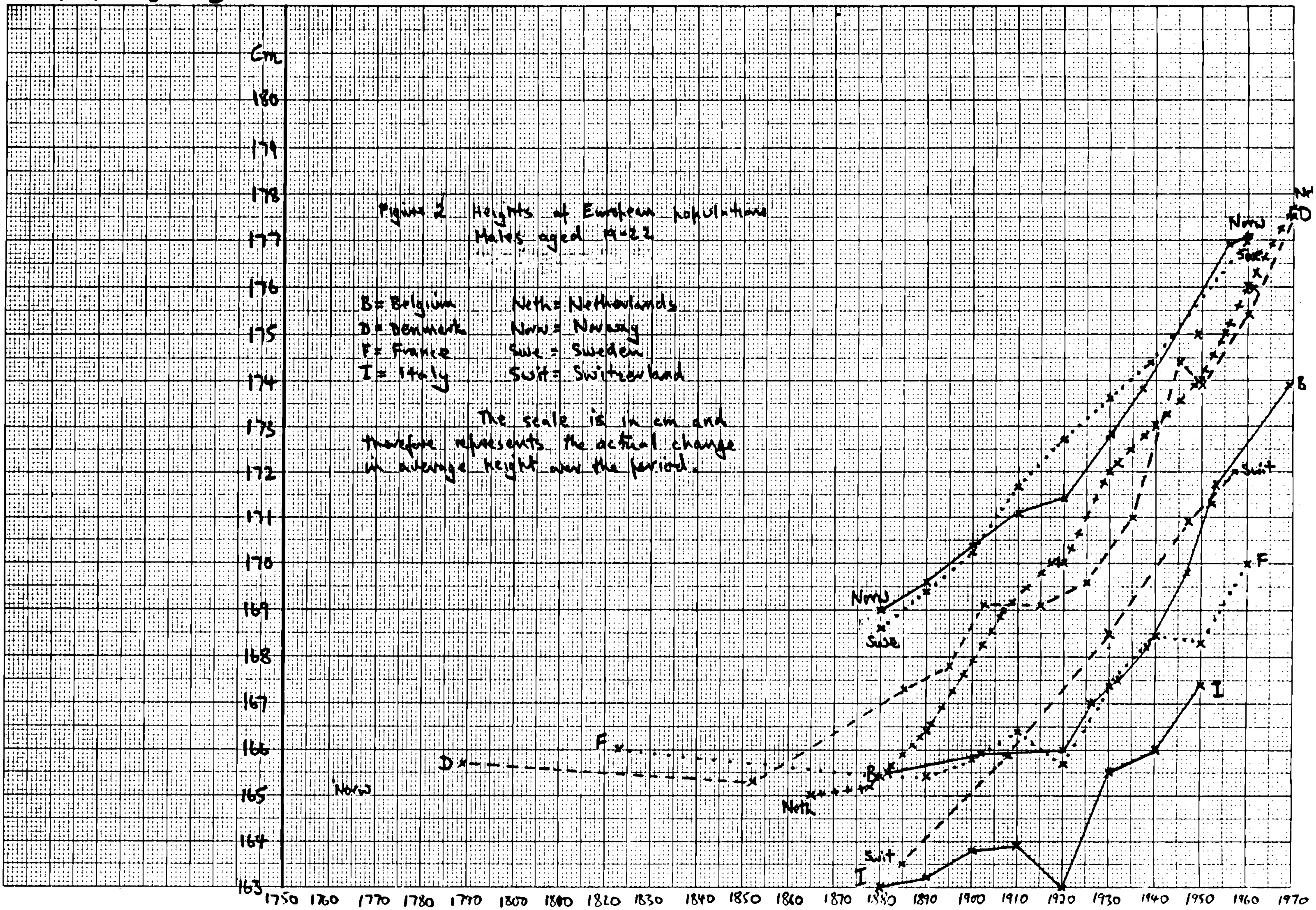
Figure 2 Heights of European populations
Males aged 19-22
B = Belgium
D = Denmark
F = France
I = Italy
Neth = Netherlands
Norw = Norway
Swe = Sweden
Swit = Switzerland
The scale is in cm and therefore represents the actual change in average height over the period.
Cm
180
179
178
177
176
175
174
173
172
171
170
169
168
167
166
165
164
163
1750
1760
1770
1780
1790
1800
1810
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
Norw
Swe
Swit
Neth
F
D
B
I

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