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Global Height Trends and the Determinants of Anthropometric Welfare, 1810s – 1980s

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Introduction

Human stature is now a well-established indicator for the biological standard of living, as it is typically correlated with health, longevity, and nutritional quality.¹ Anthropometric research on individual countries has made a significant contribution to welfare economics over the past decades, and a number of comparative volumes have collected and compared those country studies (among others, see Steckel and Floud 1997, Komlos and Baten 1998, Steckel 2009). However, until now no study has collected all existing evidence. Our study makes this contribution, and we estimate the height trends by world region. Secondly, we assess the determinants of height differences and height changes. Of course, this second analysis will only be possible for a subsample for which all explanatory variables are available.

The aim of our study is to include all the information which has been estimated in previous research. 152 countries can be taken into account.² Height estimates will be presented on a decadal basis. However, it is clear that not for all of those countries continuous series are available, some countries are only documented by one or two height estimates. The idea of this project is that subsequently additional information is entered to improve this database of world-wide height estimates over the next years. The series on individual countries will clearly contain a fair bit of measurement error, even when measurements are available and can be based on sufficient numbers of cases: often the regional and social composition of height samples cannot be perfectly assessed for being representative or not. The basic strategy to cope with this is to collect data for a large number of countries. Hence measurement errors will cancel out for most world regions. Such a work can also be important for further data collection efforts, as it is helpful to have a realistic range to compare new height estimates to.

We study the development in each world regions. When the first era of globalization boomed during the late 19th century, the New World food exporting economies could, for example, have lost some of their initial height advantage (O'Rourke and Williamson 1999). This study will also focus on one of the most important questions in anthropometric history: what determines heights? Apart from general purchasing power and the disease environment, we would expect heights to be also influenced by the availability of high-quality food stuffs (such as milk and meat). Those food items have been identified in previous research as having a bottleneck-type importance for anthropometric values due to their content of high-quality proteins and calcium. Apart from the nutritional value, historical populations needed large amounts of protein to generate antibodies to fight infectious disease (as well as those in today's Less Developed Countries, see Baten 1999).

¹ Only few exceptions come to mind, for which height and longevity do not correspond as the Japanese who consumed very little protein before the economic boom of the 1960s and had short statures. But the Japanese achieved relatively high longevity values by investing in personal hygiene and health-related education.

² We include all countries with more than 0.4 million inhabitants on which evidence was available.

Methodological issues

How can we estimate a world height trend over the period 1810-1980? Especially the poor and less literate countries tend to be poorly documented for the period before the middle of the twentieth century, but we mobilized not only the vast anthropometric history literature, but also a large number of contemporary anthropological measurements will allow to include regions in Africa, Southeast Asia and other parts of the world. After about 1950, the availability of sources changes dramatically, because the Demographic and Health surveys and similar sources provide a large amount of height data on women born between the 1950s and 1980s (sources are documented in a source appendix).

Therefore, for the 1950s-80s period, much more data is available on women than on men, whereas for most of the previous period the opposite is the case. The reason is the demographic and health interest in mothers, and in female behaviour in general. Certainly, male and female heights are not perfectly correlated, but to a certain extent they are related (Baten and Murray 1999, Moradi and Guntupalli 2006). Hence we would like to estimate this relationship between male and female height. If we dare the assumption that height trends were broadly similar this allows to transform female heights into male height equivalents or vice versa, where heights for only one of the genders are available.³ As most historical height estimates are for males, we mostly transform into male equivalents. We estimated specific regression equations for each world region in order to account for potential differences, although in most cases the conversion equations were quite similar. We can therefore in principle express heights as male equivalents. A refinement of this estimation strategy would be to take gender discrimination proxies (such as relative life expectancies, relative child mortality age 2-5 etc.) into account.

We took care to adjust heights of still growing individuals to their most likely adult height level, following the method explained in Baten and Komlos (1998, notes to table 1). For example, an 18-year-old conscript in a population that was shorter than 170 cm certainly had some remaining growth to expect.

³ A possible objection to this procedure could be based on the female resiliency hypothesis, which says that women's heights are for biological reasons more resilient to adverse conditions. However, Guntupalli (2005) recently rejected this hypothesis based on a much larger sample of male and female heights than was available before.

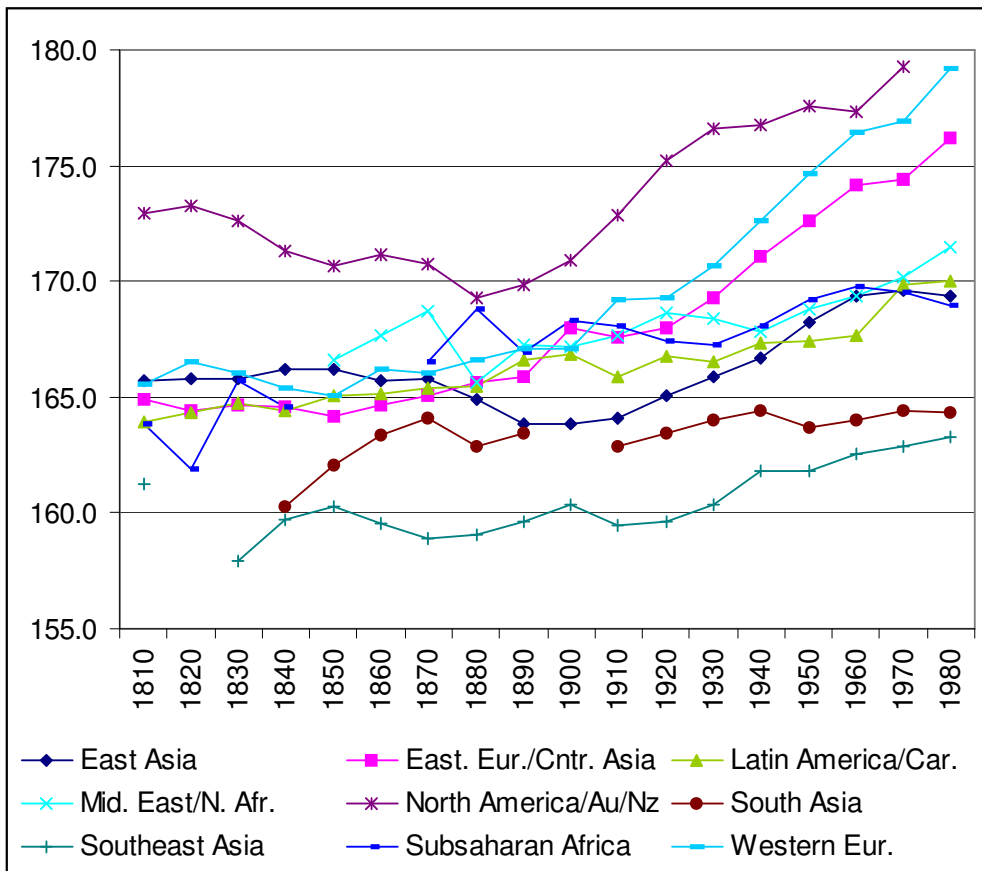


Figure 1: Height trend for all world regions

Estimates of height trends

Figure 1 has the first estimates of the world region trends for the 1810-1984 period. Those are based on population-weighted averages of 152 countries, without using interpolations. We used mostly the standard world region classification, except for the group “North America, Australia and New Zealand” that we aggregated, because those countries have quite similar characteristics (European settlers, high income and cattle per capita values). We observe that the North America/Australia/New Zealand group had very high initial values, but their values converged to the lower levels of other world regions during the late 19th century. During the early 20th century, their height advantage over Western Europe increased again, but the latter region started a notable convergence during the 1950s and 1960s, which has also been called the “Golden Age”. Eastern Europe and the socialist part of central Asia followed Western Europe, but with a certain lag. This world region lost ground during the 1960s to 1980s period, relative to Western Europe. East Asia was not far from Western Europe during the early 19th century, but fell back during the later 19th century, and formed a middle group of world regions during the late 20th century, jointly with Latin America, Subsaharan Africa, and the Middle East. African heights were the only ones declining in the 1960-1980 period (see also Moradi

2009). The shortest height could be observed in the two world regions of South Asia and Southeast Asia.

Height and GDP

Height and GDP are two different measures of welfare. GDP per capita measures the purchasing power of a nation, whereas height is more correlated with the quality of nutrition, health and equal distribution of resources. Clearly, both can also potentially serve as an explanatory variable explaining the other, but here we prefer to consider them as two different welfare indicators.

Originally, the literature had assumed a close correspondence between those two variables (Fogel et al. 1982). In the literature of the past two decades, some important deviations between height and GDP were found. Even between height and real wages for unskilled labour such deviations existed, which presumably was not caused by increasing inequality (among many others, see the pioneers Margo and Steckel 1983, Komlos 1996). However, there was a strong focus on two important cases, the UK and the United States of America. In many other countries, the relation between real wages and heights was actually much closer (Baten 2000).

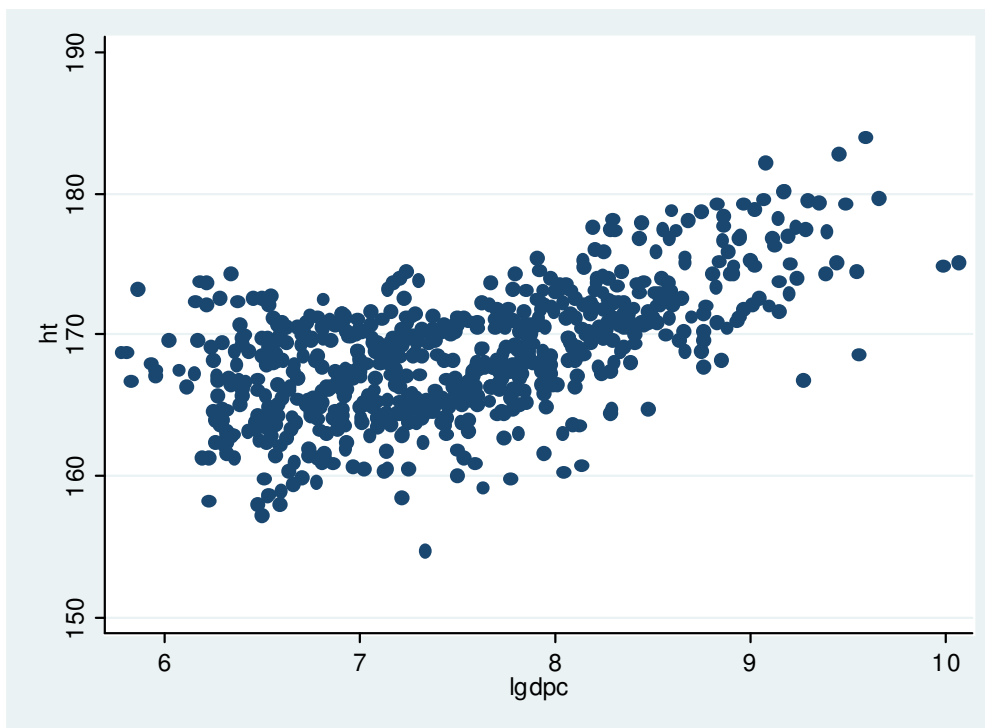


Figure 2: Correlation between (log) income per capita and height. Sources GDP: Maddison (2001); Heights: see data appendix.

In a simple scattergram, there is some positive correlation between real GDP per capita and height (correlations coefficient is 0.59, p-value 0.00). In general, there is only a modest number of cases

between 155 and 160 cm (mostly in central America and South East Asia), and a limited number of heights above 180 cm. The most solid block of observations is between 160 and 172 cm, indicating that those values were typical in the past two centuries. One deviation to the lower right is Japan, but for the Japanese values alone there was also a positive correlation between GDP and height over time⁴. Deviations on the upper left include some East Asian and African Sahel zone countries (Chad, Burkina Faso, Mali). The latter were poor in purchasing power, but had relatively good protein per capita values and tall heights. Recently, for some of the outlying East Asian countries, the GDP level has been reestimated, which actually brought those cases closer to the regression line of heights and GDP (Fukao et al. 2007).

Determinants of height

For a subset of the height data, we could generate a number of explanatory variables that cover important height determinants, such as nutritional quality, health environment, and political institutions that might determine inequality levels. We tested the residuals of our regressions below for unit roots using the Fisher test (Maddala and Wu 1999), which resulted in a $\chi^2(112)$ value 268.63, p-value 0.00. As the null hypothesis of the Fisher test is formulated in a way that the series are non-stationary, we can conclude that there is not a unit root problem. However, inspecting the usual autocorrelation statistics and a brief glance at Figure 1 suggests that there is autocorrelation. Hence we decided to estimate with a panel data model using feasible GLS, with an AR(1) autocorrelation structure.

We include different variables to control for the availability of animal protein per capita, which was a particular bottle neck factor in historical human nutrition. The relative scarcity was substantial, because it requires larger amount of inputs to produce a protein calory than, say, a grain calory (Baten 1999). Sources for those calculations are mainly Mitchell's statistics and Federico's new estimates (Mitchell 1993, Federico 2005). The model in the first column of Table 1 uses the per capita availability of livestock (cattle per capita), since cattle is a valuable supplier of both meat and milk. This indicator is available for a large number of observations, but it does not account for productivity per piece of cattle. The second model replaces cattle per capita by the annual output of meat per capita. In model three we estimate the amount of milk p.c. As a result, animal protein availability had a positive impact on height, and the coefficient for cattle per capita never misses customary levels of significance.

⁴ In the longer version, we study in more detail whether Japan was a special case, as incomes were relatively high, but heights low. Although Japanese heights increased dramatically in the post-war period, Japan is still an outlier in this respect. Possible explanations range from dietary customs to the fact that there might be intergenerational effects (heights of babies of short mothers cannot increase beyond a certain value, biological mechanisms protect mother and baby from problems during birth)

There might be some relationship between the protein effect and the inclusion or exclusion of world region dummies, perhaps because its consumption is more important in Europe and European settlements. Columns 4 and 5 demonstrate that the coefficient for meat increases in size, if world region dummies are omitted, whereas the one for cattle pre capita remains almost constant. We conclude, that the world region dummies do not change the influence of animal protein very much, at least not in the larger sample based on the cattle indicator.

We include infant mortality rates to control for disease environment (Mitchell 1993). The results confirm our expectations: a problematic disease environment is associated with lower heights.

Democracy was included to assess the possible effect of institutions on the distribution of nutrition and health resources: could it be that rich non-democratic governments (for example, in oil-producing countries) generate a lower standard of living for the population? We actually find that there was a small positive effect of democracy on heights, although it was often not significant⁵. We conclude that democracy and the more egalitarian economic structure that is usually correlated with might create a positive environment for the biological standard of living. Apart from this inequality-related effect, democracy might also have been a proxy for general development.

⁵ In the longer version, we also test dummy specifications.

Table 1: Determinants of height. Panel data model using feasible GLS, with an AR(1) autocorrelation structure

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---------------------------|------------------------|------------------------|--------------------------|------------------------|-------------------------|------------------------|-------------------------|
| Period | Overall | Overall | Overall | Overall | Overall | 1870s-1940s | 1950s-1980s |
| Cattle (log p.c.) | 0.99*** (0.000066) | | | | 1.00*** (0.000020) | 1.31*** (0.000082) | 0.65** (0.048) |
| Meat (log p.c.) | | 1.65*** (0.0000042) | | 2.08*** (3.96e-10) | | | |
| Milk (log p.c.) | | | 1.76*** (0) | | | | |
| Infant mortality (log) | -1.92*** (3.58e-09) | -0.94** (0.030) | -1.63*** (0.000095) | -1.93*** (0.000020) | -2.99*** (0) | -4.24*** (1.82e-10) | -2.14*** (0.0000086) |
| Democracy (-10-+10 scale) | 0.03 (0.29) | 0.06* (0.062) | 0.04 (0.28) | 0.09*** (0.0070) | 0.07*** (0.0067) | 0.05 (0.14) | -0.01 (0.86) |
| Mountains (in %) | -0.04*** (0.00024) | -0.04*** (0.0053) | -0.08*** (0.00000093) | -0.07*** (0.000050) | -0.06*** (0.0000098) | -0.02* (0.068) | -0.04*** (0.0025) |
| Eastern Eur/C.Asia | 5.25*** (0.00030) | 4.46*** (0.0085) | | | | 5.77*** (0.00010) | 7.31*** (0.00014) |
| Latin America | -0.82 (0.56) | -2.34* (0.058) | | | | 2.68* (0.095) | -0.37 (0.83) |
| Middle East/N Afr. | 3.69*** (0.0092) | 1.86 (0.17) | | | | 7.22*** (0.000077) | 4.18** (0.011) |
| North America/Au/Nzld | 6.27*** (0.000070) | 4.83*** (0.0027) | | | | 5.63*** (0.00026) | 7.80*** (0.000063) |
| Subsah. Africa | 1.39 (0.32) | 0.13 (0.91) | | | | | 2.32 (0.16) |
| Western Eur. | 5.88*** (0.000017) | 4.06*** (0.00037) | | | | 5.66*** (0.000038) | 6.99*** (0.0000083) |
| South Asia | -1.49 (0.41) | -4.26** (0.013) | | | | | -0.85 (0.66) |
| Southeast Asia | -1.87 (0.18) | -3.64*** (0.0073) | | | | | -1.86 (0.25) |
| TIME DUMMIES INCL? | YES | YES | YES | YES | YES | YES | YES |
| Constant | 184.07*** (0) | 190.73*** (0) | 192.59*** (0) | 198.44*** (0) | 195.98*** (0) | 194.36*** (0) | 180.34*** (0) |
| Observations | 348 | 211 | 183 | 211 | 348 | 107 | 195 |
| Wald-chisq. | 621.2 | 505.2 | 244.3 | 248.3 | 337 | 417.6 | 424.3 |
| p-value | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Notes: P-values errors in brackets. All estimates are FGLS panel estimates. Sources are available in a separate appendix.

A variable that is used in anthropological studies is the share of mountainous areas. For example, Harrison and Schmidt (1989) argued that humans are generally shorter in high altitudes (such as Peruvians in the Andes). One could imagine that this might be caused by economic variables as well, because mountain dwellers in today's LDC are often poorer. Previous studies on mountain regions within Europe often featured taller populations compared with lowlanders nearby (such as the Alps, Scottish highlands, the French Jura). The disease environment might be more favourable in sparsely populated mountain regions. It has been argued in previous studies that it was the proximity to protein that allowed those European mountain dwellers to acquire better nutritional status, which

is plausible as the same applies to other (non-mountainous) dairying intensive regions such as the continental North Sea coast (Baten 1999). Here we have the possibility to control for the disease environment and the proximity to protein, and to assess whether there is a residual effect of mountainous landscape. After controlling for the protein proximity and disease effect, the results on a global scale indicate that a higher share of mountainous terrain leads in fact to lower heights.

We also included a full set of birth decade dummies and world region dummies. The constant refers to East Asia. The world regions of Europe and North America/Australia/New Zealand have consistently positive coefficients, relative to the reference category. Including the world region dummies does not change signs of coefficients of the nutrition, disease, and political variables. Hence while some of the variation was between world regions, even within the world regions heights are determined by the economic and political factors we assess.

Finally, we could distinguish an early and late period with sufficient numbers of observations, the 1870s to 1940s (“early”) and 1950s to 1980s (“late”).⁶ We find that in the early period, both the country-specific output of protein as well as our disease proxy had a relatively large coefficient, implying that a one percent change had greater effects in the early period. In the later period in contrast, protein might have been less important, as proteins became much more easily tradable between countries, using refrigeration and other techniques, and medical technology spread around the world. A second major difference between the early and the late period is that the coefficients of the world region dummies are increasing for the European countries and North America, but shrinking for the Middle East and Latin America, after controlling for the explanatory variables. Relative to the former, East Asia lost ground, but relative to the latter, they gained somewhat. The results are actually not much different, if we include log GDP per capita as a general indicator of purchasing power (Table 2).

In the longer version of the paper, we address a number of issues such as dynamic structure, multicollinearity, endogeneity, the size of the coefficients, measurement quality of the variables, and the selection of countries for which the explanatory variables were available and test some further variables such as tropical zones and wars.

⁶ For the period before, not enough countries could be documented with all explanatory variables.

Table 2: Determinants of height, including GDP per capita. Panel data model using feasible GLS, with an AR(1) autocorrelation structure

Table 2: Determinants of height, including GDP per capita. Panel data model using feasible GLS, with an AR(1) autocorrelation structure

| | (1) | (2) | (3) |
|----------------------|--------------------------|------------------------|----------------------|
| Period | 1870s-1940s | 1950s-1980s | Overall |
| Cattle (log p.c.) | 1.10*** (0.00043) | 0.63** (0.049) | |
| Meat (log p.c.) | | | 0.57** (0.048) |
| GDP (log p.c.) | 1.72*** (0.0047) | 0.93* (0.069) | 1.09** (0.031) |
| Infant mortality | -3.62*** (0.00000015) | -1.62*** (0.0016) | -0.66 (0.15) |
| Democracy | 0.03 (0.38) | -0.02 (0.55) | 0.04 (0.17) |
| Mountains | -0.02 (0.10) | -0.03*** (0.0016) | -0.04*** (0.0054) |
| Eastern Eur/C.Asia | | 6.91*** (0.00020) | 4.36*** (0.0084) |
| Latin America | 3.25** (0.048) | -0.65 (0.69) | -2.40** (0.048) |
| Middle East/N Afr. | | 3.90** (0.014) | 1.92 (0.15) |
| North America/Au/Nz. | 5.47*** (0.00045) | 7.05*** (0.00026) | 4.15*** (0.0090) |
| Subsah. Africa | | 2.77* (0.086) | 1.04 (0.41) |
| Western Eur. | 5.75*** (0.0000033) | 6.59*** (0.0000019) | 3.61*** (0.0014) |
| South Asia | | -0.54 (0.77) | -3.27* (0.056) |
| Southeast Asia | | -1.49 (0.34) | -3.04** (0.023) |
| TIME DUMMIES INCL? | YES | YES | YES |
| Constant | 176.98*** (0) | 170.83*** (0) | 178.42*** (0) |
| Observations | 103 | 210 | 221 |
| Wald-chisq. | 405.4 | 457.4 | 534.5 |
| p-value | (0.00) | (0.00) | (0.00) |

Conclusion

This study was a first step to introduce a new data set on heights in 152 countries, and to estimate height trends by world region. We find that major determinants of welfare are high-quality nutrition and disease environment. Furthermore, both the political system and the geographic conditions also have at least a modest influence. We find a certain difference between the early and late period of global height development. In the period of the 1870s to 1940s, unit changes in country-specific

protein output per capita and disease environment (proxied with infant mortality) had a larger impact on heights.

We also find that most of the anthropometric divergence between today's industrial and developing countries took place after the 1880s. For example, the Middle East/North Africa region had impressive levels until 1880, but only modest growth thereafter. South Asia had a disappointing development, and also South East Asia grew only modest. Africa did not perform as bad as perhaps expected in the 1900-60 period, but experienced a height decline since then. When the first era of globalization boomed during the late 19th century, the New World food exporting economies seem to have lost in fact some of their initial height advantage. An additional factor might have been immigration to this world region, which led to higher population densities, less protein per capita, and different nutritional and agricultural practices.

References

<https://www.wiwi.uni-tuebingen.de/cms/fileadmin/Uploads/Schulung/Schulung5/Paper/Batenblumdurhamreferences.pdf>