The biological standard of living and body height in colonial and post-colonial Indonesia, 1770–2000

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3 authors:

Joerg Baten
University of Tuebingen

Mojgan Stegl
University of Tuebingen

Pierre Van der Eng
Australian National University

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Joerg Baten
University of Tuebingen and CESifo, Germany
joerg.baten@uni-tuebingen.de

Mojgan Stegl
University of Tuebingen, Germany
mojgan.stegl@uni-tuebingen.de

Pierre van der Eng
Australian National University, Australia
pierre.vandereng@anu.edu.au (corresponding author)

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Joerg Baten
University of Tuebingen and CESifo, Germany
joerg.baten@uni-tuebingen.de

Mojgan Stegl
University of Tuebingen, Germany
mojgan.stegl@uni-tuebingen.de

Pierre van der Eng
Australian National University, Australia
pierre.vandereng@anu.edu.au (corresponding author)

Abstract

This paper analyses the relationship between economic growth and improvements in the standard of living, indicated by average heights. It uses four sets of anthropometric data to construct time series of average human height since the 1770s. The paper observes a significant decline of heights in the 1870s, followed by only modest recovery during the next three decades. Both are related to a sequence of disasters. Average heights increased from the 1900s, accelerating after World War II. The Japanese occupation and war of independence in the 1940s were a set-back. Average height growth is related to improvements in food supply and the disease environment, particularly hygiene and medical care. GDP per capita and average height followed each other in broad terms, but the correlation is far from perfect. The paper offers several hypotheses to explain this fact.

Key words: human heights, Indonesia, welfare, economic development
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Long-Term Economic Growth and the Standard of Living in Indonesia

1. Introduction

What is the relationship between economic growth and changes in living standards? It is known that levels of GDP per capita and rates of economic growth are not necessarily good indicators of the levels and changes in the standard of living, particularly in less-developed countries. Heston (1994) explained that GDP data are established in a relatively uncontroversial national accounts framework, but that data for less-developed countries are of variable quality and may contain shortcomings that prevent their use for the purpose of comparative analysis. In addition, there is no unambiguous way to quantify the standard of living, or the quality of life. Notwithstanding the widespread use of the UNDP's Human Development Index – which actually comprises only three indicators (Crafts 1997) – there is no general agreement about what indicators of the standard of living to use, and what weights to give them for the purpose of aggregation. For example, Easterly's (1999) detailed analysis found that GDP per capita had an impact on the quality of life for at most 31 of 81 possible indicators during 1960-1990. He speculated that there may be longer lags between economic growth and changes in the quality of life than 30 years.

Since the publication of work by Robert Fogel (1994), the 1993 winner of the Nobel prize for economics, long-term changes in living standards are increasingly analyzed in both development economics and economic history on the basis of changes in average heights, particularly where national accounts data are ambiguous or non-existent (*e.g.* Micklewright and Ismael 2001; Moradi 2008). Human height in adulthood captures an accumulation of factors that contribute to changes in the standard of living of a generation of people, in particular changes in the quantity and quality of nutrition and changes in hygiene and health care that all impact on human growth during childhood and adolescence. Human heights are also used in studies on living standards and the size distribution of income and wealth in less-developed countries where other data are not readily available, or are unreliable (*e.g.* Deaton 2007; O'Donnell *et al.* 2009).

Indonesia is such a less-developed country. Its national accounts data are now of reasonable quality, but at least until the methodological revisions of 1993, Indonesia's official national accounts data are of questionable reliability (Van der Eng 2002a). Hence, for the analysis of long-term changes, alternative indicators of economic growth and changes in the standard of living are required. A few other indicators of living standards, such as life expectancy, infant mortality, educational attainment or per capita food supply are available (Van der Eng 2002b), but their reliability is questionable going back in time. Consequently, two major studies found it difficult to strike a balance between contrary views on the long-term development of living standards in Indonesia (Booth 1998: 89-134; Dick *et al.* 2002: 133-35, 157-58). Nevertheless, they echoed the very common argument that Indonesia since the 1970s experienced 'growth with equity' as a consequence of the 'pro-poor growth' policies pursued by its government that yielded low rates of income inequality (*e.g.* World Bank 2005: 126-127). This argument that economic growth in recent decades improved living standards equally across the board does not sit easily with recent evidence of significant income inequality (Leigh and Van der Eng 2009). The purpose of this paper is to contribute to these discussions in the literature on the basis of an analysis of long-term changes in average heights of men and women in Indonesia.

Indonesia has not yet featured in studies that used anthropometrics to assess changes in the biological standard of living in less-developed countries, such as in Africa (*e.g.* Moradi 2009) and Asia (*e.g.* Baten *et al.* 2010). The lack of readily available data long prevented the analysis of anthropometric data for Indonesia (Van der Eng 1995). This paper analyses for the first time data from several sources for this purpose. To analyse changes in average heights, several determinants of height have to be taken into account, rather than only changes in average income. In particular, changes in nutritional status, as well as the disease environment and hygiene and health care, are relevant.

Before it is possible to present our analysis and its contribution to the existing literature, sections 2-5 discuss the four data sources we use to assess long-term changes in human heights in Indonesia by decade from the 1770s to the 2000s. This is important, because the data sources are disparate and not necessarily representative samples. All data are presented by birth decades. Section 2 discusses data of slaves in the city of Batavia (now Jakarta), containing data for birth cohorts in the late 18th century. Section 3 elaborates a data set containing heights of migrants to Surinam for birth cohorts from the mid-19th to early-20th century. Section 4 details a compilation of data from published anthropological and medical studies for the mid-19th century to the 1930s. Section 5 discusses data from a large-scale socio-economic and health survey conducted in the 1990s and 2000s, which yields adult data for birth cohorts in the 1940s to 1980s. Some further evidence on the heights of children and adolescents complements the latter data set and brings the heights data available for analysis up to the 2000s. Section 6 analyses the long-term trends in the biological standard of living in Indonesia, while section 7 concludes.

2. Data on the heights of slaves in Batavia, 1770s-1810s

The first dataset we use consists of a list of slaves in the city of Batavia (now Indonesia's capital Jakarta), compiled in 1816 for the purpose of collecting tax from slaveholders. Slavery was a common institution in Southeast Asia, and also in Batavia under Dutch colonial rule. During a brief English interregnum of 1811-16, the new government sought to undermine the institution with the purpose of abolishing it. In 1812 it proclaimed an annual tax on the owners of slaves in Java, for which purpose slave registers were created (Paulus *et al.* 1919, vol.3: 803-4).[1] The registers recorded name, age, height and region of origin of each slave. Information about the slaves was provided by the owners. The place of origin was in most

[1] Abeyasekere (1983) discusses the slave register of 1816 on the basis of a 10% sample.

cases the port from where a slave had been transported to Java. Slaves may sometimes have been unaware of their age, in which case the owner had to estimate it. The penalty for non-registration was the emancipation of the slaves, which suggests that owners had an incentive to register their slaves with accurate data.

Eltis (1982) argued that slaves transported from Africa to the Americas represented a relatively unbiased sample of the African population in terms of height.[2] Likewise, slaves in Batavia were most likely a representative sample of the population throughout the Indonesian archipelago. Firstly, the regions of origin were relatively widespread; from Aceh in the Northwest to East Nusa Tenggara in the Southeast of modern Indonesia. Many of the Indonesian slaves were Buginese from Sulawesi in the Northeast. Other well-represented areas were Bali, Mandar and Timor, while a sizeable portion was born in Batavia as descendants of slaves. East Indonesia was well-represented in the data, because it was customary for people in this part of the country to enter slavery through sale by local rulers, debt, punishment, capture during war, or through piracy and raiding (Abeyasekere 1983: 291-3). Many slaves were born in Java, but they may have been descendants of slaves transported from elsewhere in the archipelago as an early ruling of the Dutch East India Company – the Dutch authority before the establishment of colonial rule in 1796 – prohibited the enslavement of Javanese.

Secondly, in terms of social height selectivity, the slave sample may have an upward bias, if especially tall and strong persons were enslaved through war or raiding. On the other hand, a negative social height bias can be expected if poorer people were more likely to experience debt slavery. Either way, given the relatively low average height (see below), both are not a very likely bias. The social group for comparison would be local farmers that produced for subsistence and had to meet their obligations in terms of product deliveries and labour to local rulers. Maybe the fate of these farmers was not dissimilar to that of the slaves.[3]

The register contained details of about 12,480 slaves, which yielded a dataset containing 6,580 observations (Abeyasekere 1983: 289). Of these, the key variables of gender, age and height were available for 1,209 males and 1,270 females.[4] Figure 1 shows the age distribution of this dataset. Ages between 20 and 40 are frequent, but also children and ages between 40 and 50 are well-represented. Few slaves reached ages above 50.[5] There is some age heaping in the age distribution among adults. Preferred ages are 33, 38, 43 and other ages

[2] This view is supported by Austin *et al.* (2009), who compared data on military recruits from Africa for the army in colonial Indonesia in the 19th century with Eltis' data on African slaves.

[3] On the other hand, around 1800 most of the Indonesian archipelago was still relatively sparsely populated and – with the possible exception of occasional famines caused by crop failure and epidemics – the average diet may have been sufficient for subsistence. But this assumes that the diet of slaves was sufficient as well and therefore that the cost to owners of feeding slaves was sufficiently low.

[4] The register itself does not identify gender, which was established on the basis of the names of the slaves (Abeyasekere 1983: 289, 294).

[5] In the late-18th and early 19th century, Batavia was infamous for being an unhealthy place to live. Malaria and poor water supply were most likely main contributing factors to high mortality rates (Abeyasekere 1983: 293-4). Consequently, only just over 5% of slaves were recorded as being 50 years and older.

ending with 3 and 8, whereas in most populations heaping tends to occur for ages ending in multiples of five.

(Figure 1 about here)

This preference for ages ending in 3 or 8 may be related to a difference between the moment of registration and the compilation of the aggregated list. The registration process consisted of slave owners submitting individual lists of slaves. As the slave tax started in 1813, the registration of slaves is likely to have started in 1813 as well, while the list was compiled in 1816. Consequently, the scribes assembling the list may have added one to three years to the age of each adult slave, depending on the time of registration. If most slaves had been registered in 1813, and the owners did not know the actual age of some of the slaves, heaping around the ages ending with 3 and 8 is to be expected.[6]

Figure 2 shows that height is often given as rounded feet. Most rounded height entries are for 5 feet (60 inches), some for 4 feet (48 inches), and a much smaller number is rounded to 3 or 6 feet.[7] In total, 38% of height statements were rounded to full feet, whereas the expected share of rounded measurements would have been one-twelfth or 8.3%. Komlos (2004) has shown that modest rounding by itself does not bias mean height levels. But in this case the degree of rounding in the source needs to be addressed.

(Figure 2 about here)

It is not clear what purpose the inclusion of heights in the slave register served. The government proclamation required owners to give a description of the slaves, possibly for the purpose of identification of slaves during checks by tax officials at the owner's household. Many owners recorded the height of their slaves as well as other physical features, while others only recorded identification marks such as facial scars. There is therefore no formal reason to argue that rounding was restricted to particular groups, such as children or women.

Table 1 shows the result of regressions used to test whether the rounding is correlated with gender and age. The table shows that the heights of females and adolescents were less often reported in rounded values than for men. It also shows no other statistically significant evidence suggesting correlation of rounding with other characteristics such as age and birth decade. Similar regressions for place of origin (or separate regressions for ages and birth decades) also did not yield clear patterns. Slaves from some of the less-frequent places of

[6] This calculation apparently took only place for adults, and not for children and adolescents, otherwise the presence of ages 0, 1, and 2 cannot be explained. The ages of younger slaves might have been reported every year, as age played a larger role for their value to the owner. The age groups below 28 do not have strong heaping ages ending with 3 and 8.

[7] In Batavia in the early-19th century, the Rhenish foot with 12 inches was used, which equaled 31.4 cm, or 2.62 cm per inch (Doursther 1840: 404).

origin, such as Flores, had less rounding, but this was not a general phenomenon. Hence, it must be concluded that rounding was not specific to any subgroups.

(Table 1 about here)

It appeared that rounding was only prominent in some parts of the data set, and not in other parts. The data set was numbered consecutively with integers. It is likely that a group of slaves was entered in the register by the same scribe. We distinguished groups of 100 numbers, which meant that after deletion of those with unknown gender, age and height we had groups of around 30 slaves each. Figure 3 shows that there were groups with more rounded ages, and groups with fewer rounded ages. Less rounding occurred for example for entries 1-399 and 2900-3199, while rounding was close to zero for entries 4,200-4,299.

Figure 4 shows a histogram that is based on observations from only the groups that contained less than one-third rounded observations. Figure 4 therefore shows less rounding than Figure 2, and the share of values rounded to full feet is only 21%. Some rounding can still be observed for 4 feet (48 inches) and 5 feet (60 inches), but this may be tolerated as 'modest rounding', according to Komlos (2004). Unfortunately, this procedure reduces the number of male observations to 292 and female observations to 308, as Table 2 shows.

(Figure 4 about here)
(Table 2 about here)

Table 3 shows the results of an OLS regression analysis of this remaining dataset. The age dummies of adolescents are heavily correlated with the birth decade dummies, and therefore do not yield robust results. They are therefore excluded. A joint dummy variable is used as a control for the 20-22 age group as there are insufficient observations for the individual ages. The results are almost identical if this age group is excluded. Table 3 does not distinguish between the three birth decades, as the number of observations is too small.

(Table 3 about here)

Table 3 shows that after controlling for the region of origin the average height of male adults born during the 1770s-1790s is 157.4 cm, for females 144.1 cm. Among the females, Balinese slaves and those from East Nusa Tenggara were the tallest, while among the males only those from Aceh were significantly shorter than those from Jakarta. The height of male slaves is close to the lowest level observed below for the 19th century (see below).

The adolescents in the sample were all born in the 1800s and 1810s. Previous studies have found that the years before measurement have a stronger impact on the heights of adolescents than later years preceding adulthood (*e.g.* Baten 2000). Many of the adolescent slaves may have grown up in relatively affluent households.[8] We therefore test whether these adolescent slaves benefited from being in such households and had higher height-for-age scores, compared to the adult slaves in the sample. For this purpose, we estimate the adult height of the adolescents in the 1816 slave dataset.[9] For each child, the height-for-age z-score (haz value) was calculated, which is a device to express height independent of the age of measurement. A haz value of 0 corresponds to an average child stature in the United States in the late-20th century. Haz = -1 means that the child has a growth path one standard deviation below the U.S. average. In this case, final height is expected to be 6.6 cm – or one standard deviation – shorter than 176 cm, the average US height. A child with haz = 0 would achieve an adult height of 176 cm, if the environment would not change, and a haz = -1 child would be correspondingly shorter. We find haz values of -2.36 standard deviations for male children (N = 69), after discarding extreme outliers of ± 9 standard deviations), and -2.93 for female children (N = 72). Transformed into adult height, the male children would be expected to become on average 161.3 cm later in life and the females 146.1 cm, if the nutrition remained as it was in the household of the slave owner. In both cases the adult adolescents would be taller than their adult peers in 1816. Their heights are close to the highest level observed later in the 19th century (see below). In other words, adolescents may have benefited from growing up in slave households, possibly because their diet was better than in the villages where their parents grew up, or the biological standard of living in Java as a whole improved.

3. Data on migrants from Indonesia to Surinam, 1850s-1910s

Our second data set refers to contract labourers who migrated from Indonesia to the Dutch colony of Surinam in South America. The institution of contract labour has a long history in the Indonesian archipelago. For example, the first attempt by the Dutch colonial government to regulate the practice dates back to 1819. After slavery was abolished in Surinam in 1863, plantation owners started to recruit contract workers in India as well as Indonesia. The Indonesian contract labourers were almost exclusively recruited in Java during 1888-1939 to work on plantations in Surinam. Their details, including age and height, were recorded upon arrival in Surinam. Java was a preferred area for recruitment, because increasing population growth and density implied that Javanese wage rates were relatively low.

Table 4 shows the distribution of observations by birth decade.[10] The earliest birth decade with sufficient coverage of adults was the 1850s. Later birth decades have sufficient observations until the 1910s. There are also some heights of younger contract laborers, which

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[8] Abeyasekere's (1983: 296) 10% sample suggests about that about one-third of the slaves were in respectively European, Chinese and other (*i.e.* Arab, Moor, indigenous) households.

[9] For the purpose of converting haz values into adults height equivalents, the haz-values are expressed relative to mean heights in the US (in this case 176.8288 cm), and their standard deviation (6.576107 cm). It is then possible to convert for males using the equation height = 176.8288 + 6.576107 × haz and for females height = 163.66 + 5.989 × haz

[10] We only analyze the heights of adults younger than 55 years.

can be used to cross-check observed trends in adult heights in respect of catch-up growth, as in Section 2.

(Table 4 about here)

Two potential biases in the migrant sample may have affected the oldest cohorts, since those aged over 45 may have started to shrink already, although modern longitudinal studies find this effect to be relatively modest, *i.e.* less than half a centimeter up to the age of 50, less than 1 cm until age 55.[11] Still, this could produce a downward bias among the earliest cohorts. On the other hand, those who survived to ages 50 or 55 may have been better-nourished individuals. Moreover, a small upward bias might have been generated by recruitment, if the recruiting agents of the plantations were more selective in their choice of older recruits than younger ones. Although detailed studies found that this recruitment bias mainly concerned chest circumference (Brennan *et al.* 1994a), the possibility that this also applied to height cannot be excluded. On balance, the positive biases (selective plantation agents, survival) may have offset the negative ones (shrinking). Figure 5 demonstrates that the quality of measurements is relatively high. All measurements are in centimeters and there is little rounding on even numbers or multiples of five, except for a small amount on 160 cm.

(Figure 5 about here)

All male observations were first included in a joint regression, using age dummies for those aged 18-22. The age dummies were correlated with some of the birth decades and the results were therefore implausible. Table 5 therefore distinguishes between mature adults aged 23-55 and young adults aged 18-22, which were analyzed separately as a cross-check for the trends in the 23-55 age groups. Migrants from West Java were used as the reference group in the constant, and the 1900s birth decade. Regression analysis in Table 5 indicates that regional differences within Java, where most contract workers were recruited, did not matter much. Those born in Jakarta were consistently taller, whereas males from Yogyakarta were sometimes shorter, although not always significantly so. Heights in the three regions of rural Java appear relatively homogenous for this group. Table 5 shows that the young adults (aged 18-22) were much shorter than the mature adults. A possible reason is that in periods of poor nutrition, young males grew astonishingly long, sometimes even until their mid-20s.

(Table 5 about here)

Compared to the male birth decade constant of the 1900s, people born in the 1850s and 1860s were significantly taller. The lowest values were reached in the 1910s and the

[11] Guntupalli and Baten (2006) also arrived at low degrees of shrinkage in cross-sectional data in their study of heights in prewar India.

1880s. The trends for young males and adult males confirm each other, whereas the female height development reveals some similarities, such as the low points in the 1880s and 1910s, but also some differences, as Figure 6 confirms. The growth between age 20 (which is the constant for the young males) and adult age is still substantial.

(Figure 6 about here)

4. Anthropological and Medical Surveys Dataset, 1850s-1930s

For a similar period as in section 3, a dataset was constructed on the basis of height data for males reported in a range of anthropological and medical studies of people in Indonesia.[12] Despite some shortcomings, as will be discussed below, this dataset is a valuable resource for the purpose of cross-checking possible biases in the data in section 3. It also allows this study to extend the analysis of trends until the 1930s.

The main challenge of this dataset was that some observations are grouped data. When studying height trends, a frequent problem regarding anthropological surveys is the paucity of the information given on birth cohorts, as many anthropologists of the late-19th and early-20th century assumed that anthropometrics did not change over time. Hence, the decades of birth of the measured individuals had to be approximated, and it had to be accepted that a smaller proportion of the measured individuals was born before or after the most prominently represented birth decade. In a way, the time trend which results from these estimated birth cohorts resembles moving averages insofar as it smoothes the height development. For example, if there was a height decline in the 1880s but only 70% of the respective individuals were born in the 1880s and 30% in the 1870s, the decline would be smoothened. Koepke and Baten (2005, 2008) and Stegl and Baten (2008) estimated these grouped and individual data jointly with Weighted Least Square Regressions (WLS) in order to estimate average heights for populations for which otherwise study of anthropometric development would not be possible. This section of the paper uses the same methodology and follows Dickens (1990) by weighting each observation by the square root of its group size.

Figure 7 shows that the measurement quality in these data is quite high, as may be expected of measurements by trained anthropologists and medical practitioners. Table 6 explains that the number of cases for adult males is high enough for all birth decades from the 1850s-1920s. Table 7 shows the results of two regression models to capture trends in heights. The data yield a low point for the birth decade of the 1870s, relative to the constant which refers to the 1900s, and also low heights for the 1880s and 1890s. Table 7 confirms the taller birth cohorts of the 1850s and 1860s found in section 3, as well as the recovery of average height after the 1890s.

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[12] Data from across the Indonesian archipelago were used for this purpose, with the exception of New Guinea or West Papua. The Appendix lists the sources used for this purpose.

(Figure 7 about here)

(Table 6 about here)

(Table 7 about here)

For the 1920s and 1930s, some height data are available for young Indonesian male adults. In this case the underlying sample size is large (N = 2,020), but most of this data is grouped. The dummy variable for age group 20-21 yielded implausible values, partly because age rounding interacts here with age structure, as the observations include individuals whose age was rounded to 20. Omitting the age dummy 20-21 yields a plausible comparable increase in average height from the 1920s to 1930s as for older adults.

5. Indonesian Family Life Survey Datasets, 1940s-2000s

We used data from three rounds of the Indonesian Family Life Survey (IFLS), which comprises large-scale socio-economic and health surveys conducted throughout Indonesia in 1993, 2000 and 2007. Table 8 shows that this dataset yielded sufficient observations for adults for the birth decades 1940s-1980s. There were also some observations for the 1930s birth decade, but those people were already aged 54-55 during the 1993 survey, and may have been subject to modest shrinking. Although not all regions were covered, IFLS was organized with great care to make it is as representative as possible. Table 9 finds a strong increase in average heights between the 1940s and the 1980s.

(Table 8 about here)

(Table 9 about here)

Finally, we estimated adult heights for the 1990s and 2000s on the basis of the heights of children from IFLS. Using the method described in section 2, and using the heights of 3,031 female and 2,893 male children aged 8 to 17 born during the 1990s, as well as 3,324 female and 3,416 male children aged 4 to 7 born during the 2000s, we estimated the projected adult height. The average adult heights of males born in the 1990s and 2000s were estimated at 165.9 and 167.7 cm respectively, and females 153.8 and 156.0 cm respectively. In other words, economic development in Indonesia during the 1990-2007 had very positive effects on the stature of children born during these years. If those relatively favorable circumstances continue, they are likely to acquire a higher adult stature than their parents.

6. Long-Term Trends in Heights in Indonesia

Figures 8 and 9 draw the evidence from Sections 2-5 together and present long-term trends in average heights of respectively adult males and females in Indonesia during more than two centuries. These are trend estimates after controlling for differences in the four samples in terms of age and region of origin. For the 1810s, 1990s and 2000s, the data are estimated on the basis of the heights of children. For decades for which only heights of young male adults (aged 18-22) were available (*i.e.* the 1930s), the adult height level in the previous decade was used, to which the change in height of young adults was added. For example, the 1930s estimate is the adult height level of the 1920s plus 0.21, the coefficient of the 1930s for the heights of young adults.[13]

Figures 8 and 9 reveal broadly similar trends of average heights of males and females. The only significant difference concerns the gap between male and female heights in the 1770s-1790s and the estimated height of slave children in the 1810s, which was higher than later in the 19th century. This may suggest that male heights in especially the 1810s were overestimated. Nevertheless, assuming that slaves were relatively representative for the Indonesian population, there may also have been an upward trend between the pre-colonial birth cohorts of the 1770s-1790s and the 1850s birth cohort.

Another key feature in Figures 9 and 10 is the decrease in average heights of especially adult males in the birth cohorts of the 1870s and the very slow recovery during 1880s-1900s, and the decrease of the heights of females in birth cohorts of the 1870s and 1880s. The decrease of female heights in the 1910s birth cohort may be related to a low number of observations, as Table 4 showed. But how can the trends during the 1870s-1900s be explained?

Most anthropologists agree that modest or severe malnutrition – particularly in infancy and childhood – in interaction with a disadvantageous disease environment is a major cause of stunted growth in developing countries today (Bogon 1988). It is difficult to be specific about the impact of specific events, but Indonesia did suffer the consequences of four disasters during these decades, particularly the core island of Java. Firstly, a series of droughts during the 1870s-1900s, particularly 1875, 1877-78, 1885-86, 1888-89, 1891, 1896-97 and 1902-03 (Van Bemmelen 1916; Paulus *et al.* 1918, vol.2: 339), which had a negative effect on the production of rice, the main staple crop in the core island of Java at a time when new technologies to advance rice production were still at least 20 years away (Van der Eng 1996).

Secondly, the 1883 eruption of the Krakatau volcano off the coast of West Java was one of the biggest volcanic disasters in human history. The eruption and the subsequent tsunami claimed an estimated 36,147 deaths (Tanguy *et al.* 1998: 139) and affected rice production in Java's coastal regions. The enormous quantities of ash released by the eruption and the subsequent showers of ash pouring down also affected crop production across the Indonesian archipelago.

Thirdly, the 4th (1864-75) and 5th (1883-96) global cholera pandemics were brought to Indonesia by Muslim pilgrims returning from the annual Hajj to Mecca. Cholera was at that time endemic in Indonesia, and contributed to significant spikes in mortality rates, such as

[13] There is also evidence on 54-55-year adults born in the 1930s, but their height is probably affected by old-age shrinking, which has been estimated to be around 1 cm at this age. Adding 1 cm to their age, actually fits the estimate based on the 18-22 year-olds quite well (the height of those aged 54-55 is still one centimeter lower, but the gap to those aged 18-22 is smaller). Hence we added this adjustment for old-age shrinking in Figure 8.

during 1874-75 and 1881-84 (Boomgaard 1987: 50; Gardiner and Oei 1987: 71), although other diseases such as dysentery, malaria, smallpox and measles contributed as well.

Fourthly, a massive outbreak of cattle plague took place during 1879-1883 for which the only solution at the time was the wholesale slaughter of infected and suspected animals (Spinage 2003: 487). In all, the stock of buffaloes in Java declined by 17% relative to 1878, particularly in West Java. This is likely to have had a negative effect on food supply, because buffaloes were crucial to the preparation of fields for rice production and as a source of protein. The cattle plague problem flared up in 1889-93 and 1897-99 (Paulus *et al.* 1921 vol. 4: 522) until it was finally eradicated in 1911.

During this period per capita food supply was only 1,600 to 1,750 Kcal per day in Java, just enough for subsistence and physical labor on small farms (Van der Eng 2000: 596-7). But such disasters occasionally obstructed the production of the main staple crop, rice, and affected the delicate balance between population growth and the growth of food production in Java. Markets for food products in Java were still poorly integrated by 1880 (Van Zanden 2004: 1040), which meant that insufficient food from surplus areas reached deficit areas in Java. This contributed to food shortages and malnutrition, particularly during the months just before the next rice harvest. In turn, malnutrition enhanced stunted human growth.[14]

Such occurrences help to understand the reduction in average height during the 1870s-1900s, but endemic malnutrition and diseases also help to account for the fact that average human heights in Indonesia were long quite low by modern standards. It should be noted that today's developed countries were in the past also affected by a combination of malnutrition and a disease environment that stunted human growth. For example, the Dutch were among the shorter populations in mid-19th century Europe, because rapid urbanization had made the provision of food and particularly fresh milk costly. At that time, the American Indians (of Asian origin) in the great plains of North America were the tallest people in the world, because they had easy access to substantial amounts of animal protein, while a low population density created a beneficial disease environment. By the late-19th century, they were closely followed by Australians and Americans of European origin, who had similarly protein-rich diets. Improvements in the protein and calcium content of the average diet are likely to be an important factor in explaining average height gains, and *vice versa* (Baten 2009). As the final stature of humans is largely determined during the first years of life, the availability of those nutrients to children was crucial for the purpose of maximizing adult stature (Bogin 1988).

While not conclusive, Figure 10 suggests a close correlation between per capita protein supply and average male heights, particularly during the colonial years until the 1940s. However, the main part of the consumed protein was of vegetable origin, despite the growth of the consumption of animal products particularly in recent decades. Indonesia does not have a tradition of dairy farming. The production of milk and dairy products for human

[14] With the exception of the 1940s (see below), comparable episodes of reduced food supply and malnutrition did not re-occur in Indonesia during the 20th century, despite occasional massive volcano eruptions and droughts. Effectively, the increasingly advanced integration of markets for food crops allowed the Indonesian economy to absorb the consequences of such events to be absorbed.

consumption was long marginal and for the non-indigenous population in the country (Den Hartog 1986: 64-102). Buffaloes and cows were kept as domestic animals, but largely as draught animals for agricultural or transport purposes, and for fertilizer. Around 10% of these animals was slaughtered every year, and per capita beef consumption was only 2 to 2.5 kilogram per person, or 6 to 6.5 grams per day in the late-19th century (Van der Eng 2000: 596-7). The consumption of eggs, poultry, goat meat and mutton may have been more relevant at the time, but there are no data to confirm this. The consumption of dairy products only increased significantly since the 1970s, mainly in urban areas. Until then, the main sources of protein in the average diet in Indonesia were rice, maize and soybeans; fish and meat were luxuries. While the consumption of proteins was quantitatively sufficient, the fact that it was mainly of vegetable origin may have caused the Indonesian population to miss out on important calcium and vitamins in dairy products (Baten 1999), as well as antibodies that allowed dairy-consuming populations to withstand the impact of an adverse disease environment (Bogin 1988: 132-33). Still, the correlation in Figure 10 is imperfect, which suggests that other factors must have been relevant.

One relevant factor is that Indonesia's economy experienced gradual growth of GDP per capita after 1900, which can be taken as an indicator of a broader array of gradual changes that affected the biological standard of living, both directly and indirectly (Van der Eng 2002a). An example is a gradual increase in public spending on the services of government agencies that fostered welfare (Boomgaard 1986; Cribb 1993). In addition, physical infrastructure improved and the economy diversified, creating a growing range of new income opportunities across the country. Public facilities for health care and hygiene gradually improved, and that the negative impact of common diseases and pests on popular health gradually decreased, as for example the successful case of plague eradication demonstrates (Hull 1987; Hugo *et al.* 1987: 108-9). Nevertheless, infant mortality in urban areas was still high in the 1930s (Van der Eng 2002b), which implies that the impact of improved health case and hygiene facilities was gradual.

The opening of new land for farming and new food production technologies also contributed to significant improvements in the average diet, particularly during 1905-1920 and later since the 1960s (Van der Eng 2000). There were occasional setbacks in terms of regional food shortages that caused local famines, such as in Semarang in 1900-02 (Van der Eng 2004), as well as epidemics, particularly the Spanish flue epidemic that struck Indonesia in 1918 (Brown 1987). The economic crisis of the early-1930s reduced income opportunities and may have been a set-back for human growth, although per capita food supply decreased only marginally that decade (Van der Eng 2000; Boomgaard 2000: 44-45). Figures 8 and 9 show that the 1940s birth cohort experienced a set-back in human growth. During this decade Indonesia experienced the Japanese occupation and the war of Independence. This was a very difficult period of economic contraction and a major famine that caused the death of an estimated 2.4 million people in Java during 1944-45 (Van der Eng 2000: 605-7). After the 1940s, sustained improvements in health care and hygiene caused mortality rates to fall and population growth to accelerate (Hugo *et al.* 1987: 107-35). These changes are likely to have reduced the incidence of infectious diseases in infancy, and therefore may have benefited human growth.

Another important change was the improvement of per capita food supply since the late-1960s. Until then, population growth and the growth of domestic food production had been delicately balanced, particularly in densely populated Java, with some improvements in per capita food supply during the 1920s and 1940-41, but lower levels in the 1950s and 1960s. Underlying the growth of food production after the 1960s was the so-called 'Green Revolution' in rice agriculture, but also the development and integration of domestic markets for food products that enhanced the growth of the marketable surplus and the diversification of food production, as well as greater flows of food products from surplus to deficit areas (Van der Eng 2000: 605-7). Assisting these improvements was accelerating economic growth since the 1970s, which facilitated a significant increase in public and private investment in physical and health-related infrastructure. Infant mortality rates decreased further (Van der Eng 2002a), which indicates further improvements in health care and hygiene, which in turn encouraged human growth in Indonesia.

Having outlined the main underlying factors that help to explain long-term trends in average height in Indonesia, it is now relevant to discuss how these trends relate to long-term economic growth in Indonesia, given the fact that until 1993 Indonesia's national accounts data are tentative at best (see section 1). Figure 11 compares the growth in average male heights in Indonesia with similar trends in human growth in a selection of other countries. Heights are plotted as a function of GDP per capita, in order to see how the change in male heights in Indonesia compares with the other countries at similar stages of economic development. It may be argued that height differences across continents are related to differences in genetic potential for height growth. However, contemporary understanding of human growth is that there is no genetically predetermined maximum human height, and therefore that human heights are in principle comparable across continents (Baten 2009).

Several issues prevent a straight comparison of average height in countries at similar stages of economic development, as indicated by GDP per capita. In other words, historical levels of GDP per capita are an imperfect indicator of the standard of living, as indicated by average heights. One issue is that changes in nutrition and the disease environment may occur independent of changes in GDP per capita, and that discrepancies between countries in these nutrition and disease environment may persist, even if levels of GDP per capita are the same. For example, Indonesia in the 1980s benefited from the dissemination of new international insights into basic health care and hygiene that simply did not exist in the 1820s when The Netherlands had a comparable level of GDP per capita. In other words, it needs to be kept in mind that at any time the relationship between GDP per capita and average height depends on historical context. Nevertheless, Figure 11 shows that Indonesia's experience up to the 1950s was below the average of the six countries, while since the 1950s it was broadly in line with the average.

The relationship between economic growth and human growth was much less than the average in the case of Indonesia during the 1920s-1940s and India during the 1870s-1950s. This may be related to the fact equating GDP per capita with average income neglects two other factors. Firstly, apart from the poor quality of national accounts data in less-developed countries noted in section 1 above, there may be a significant difference between GDP and total income (or Net National Product). For example, Indonesia has long had a trade surplus to finance its foreign payments. Hence, during 1960-2008 its NNP at factor costs was on average 13% lower than its GDP at market prices, according to Indonesia's national accounts data.

Secondly, high levels of income inequality may increase the discrepancy between median and mean incomes. For example, prewar Indonesia had relatively high levels of income inequality (Leigh and Van der Eng 2009), which meant that the growth of GDP per capita did not necessarily generate a corresponding growth in median income and therefore a matching improvement in the standard of living as indicated by average height. Income inequality in Indonesia since 1982 has generally been significantly lower than in prewar years, which helps to explain that the increase in the average height of males in Indonesia since the 1950s in Figure 11 is close to the average. For example, Moradi and Baten (2005: 1234) listed several studies of heights in less-developed countries that showed that the height differences between rich and poor can be extraordinarily large, and Deaton (2008) analyzed the same phenomenon for India.

Another factor that needs to be kept in mind is the persistence of dietary customs. While the consumption of animal protein and calcium enhances human growth, the role of animal protein in Asian diets in the past was often marginal. This was the case in Indonesia (see above). But also in several other Asian countries, such as South Korea and China, per capita consumption of milk is still much lower than in the Netherlands or Scandinavia.[15] While the consumption of milk and meat has increased in Asian countries in recent decades, there has not been a corresponding increase in average height. This suggests that in addition to nutrition, the disease environment and the economic situation more generally, intergenerational effects of height might also play a role (Baten and Hira 2008: 221-223). In other words, a biological mechanism may prevent short mothers to give birth to very large children, for example the restricted size of the birth canal in women. Hence, East Asian people may still remain relatively short for another generation or two, in spite of their relatively high income and dietary changes. This might be caused by the protein-scarce nutrition of the 19th and early 20th century, but has effects until today.

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[15] Lactose intolerance was probably not the most decisive limiting factor. Lactose intolerance implies that many people in the world have digestive problems when consuming large quantities of milk after ages 5–7, when genetically lactose-intolerant people tend to lose their ability to digest fresh milk. However, lactose-intolerant people can still digest modified milk products such as *kefir* and *lassi*. Moreover, all people can drink about one cup of milk per day if their intestinal bacteria adapt to live in a milk environment through careful training. Many South Koreans consume some milk today, using this method of permanent training. We thank Barry Bogin (University of Michigan-Dearborn) and Sunyoung Pak (Seoul National University) for their observations on this issue.

7. Conclusion

In this paper we presented for the first time ever data on long-term trends in average heights of adults in Indonesia since the birth decade of the 1770s. The data were obtained from four different sources, and they were closely scrutinized for the purpose of making them comparable. These heights data were then taken as indicators of changes in the standard of living in Indonesia, and compared with available evidence on long-term economic growth in order to assess the relationship between economic growth and living standards. For that purpose the historical data were compared with those of five other countries.

We demonstrated that the 1870s and the decades that followed constituted a difficult period for Indonesia, which was related to four disasters: a sequence of droughts, the massive eruption of the Krakatau volcano in 1883, cholera epidemics and cattle plague. Recovery of these problems was slow, but during most of the 20th century, the increase of average heights was unabated, with the exception of the 1940s, particularly the years of Japanese occupation and war of independence. The gradual increase of average heights was related to a gradual improvement in the general economic situation, and more specifically to improvements in nutrition and the disease environment. Both enhanced human growth, particularly during the crucial period of infancy. While these explanations are plausible, it is not possible to be certain about the relative importance of each of these factors, which should be the subject of further research.

Nevertheless, the correlation between economic growth and improvements in the standard of living, as indicated by average height is imperfect, as the comparison of height and GDP per capita data for six countries underlines. We hypothesized that this imperfection is related to several factors. One is the fact that improvements in nutrition and the disease environment may occur independently of the level of economic development. In addition, GDP per capita itself is an imperfect indicator of average income. Further, GDP per capita takes no account of income inequality, which may distort the correlation between the level of economic development and the average standard of living. Lastly, it is possible that the dietary habits of decades ago continue to have an impact on average heights. Such factors should also be the subject of further research.

Appendix: Anthropological and Medical Studies in Indonesia

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Figure 1: Number of Observations by Age in the Slave Dataset, 1816

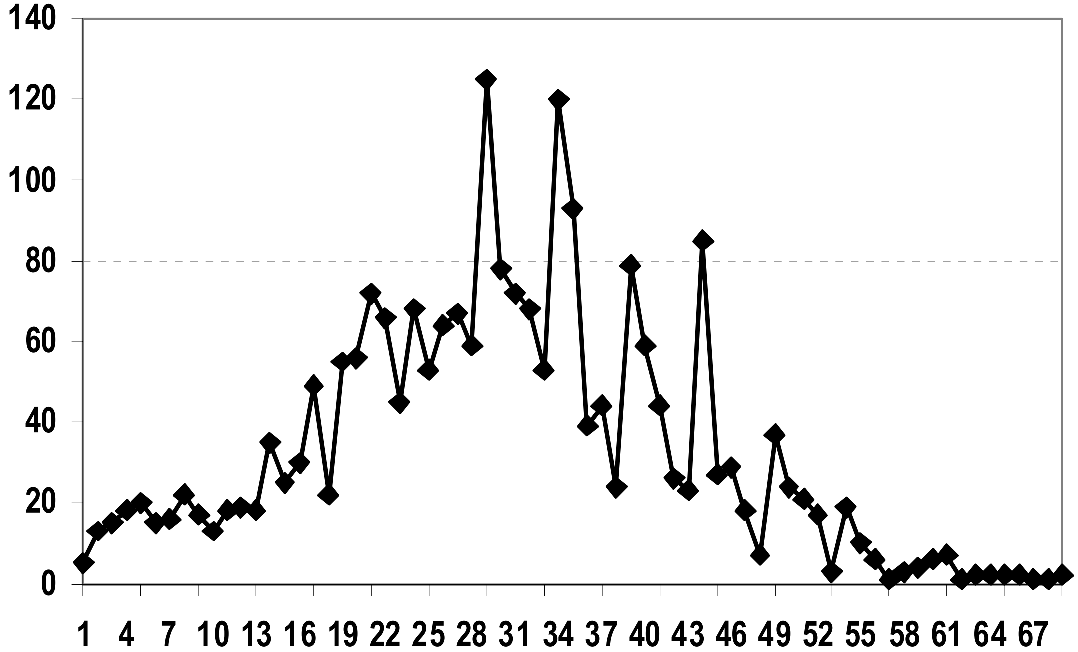


Figure 2: Rounding of Heights in the Slave Dataset, 1816

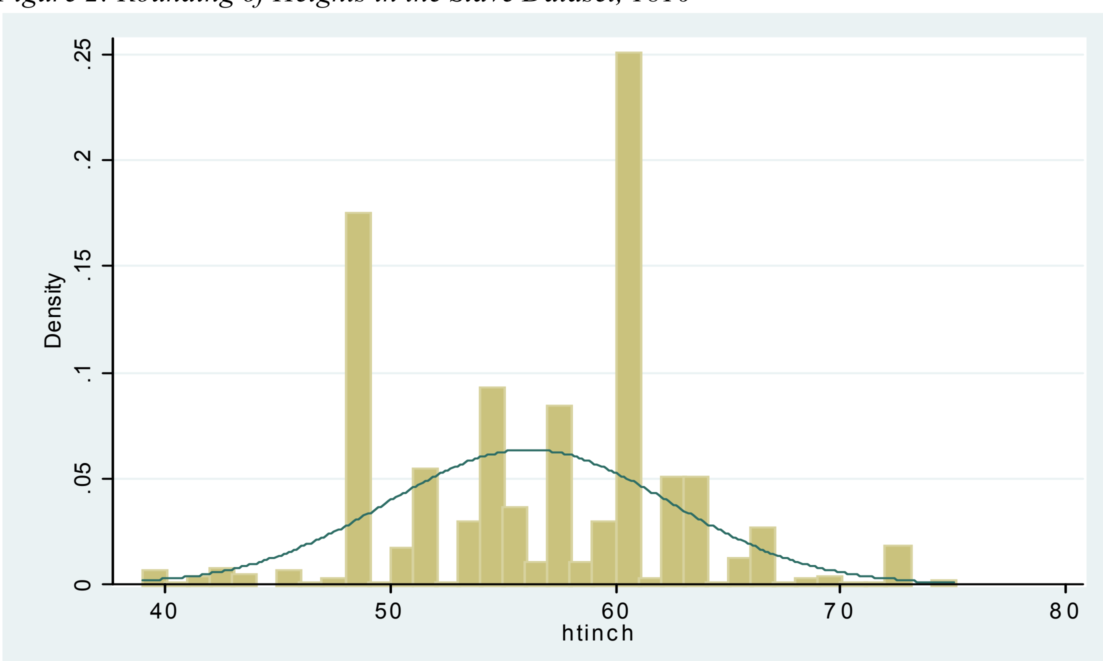


Figure 3: Share of Rounding to Full Inches by Number of Entry in the Slave Record, 1816

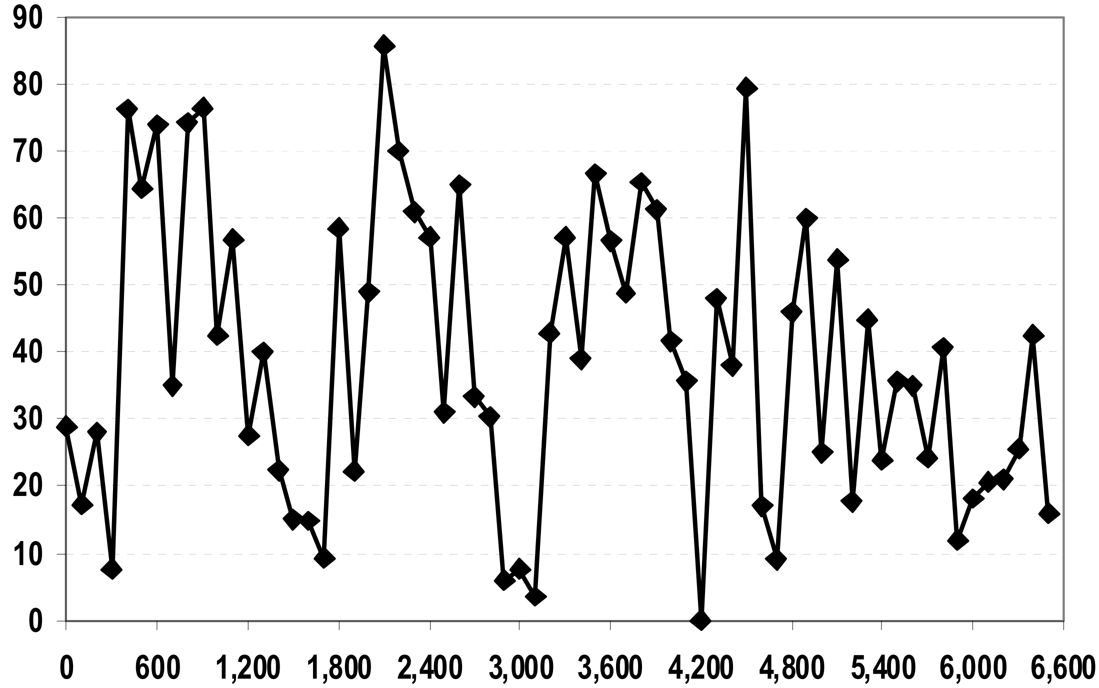


Figure 4: Height Rounding in the Reduced Slave Dataset, 1816

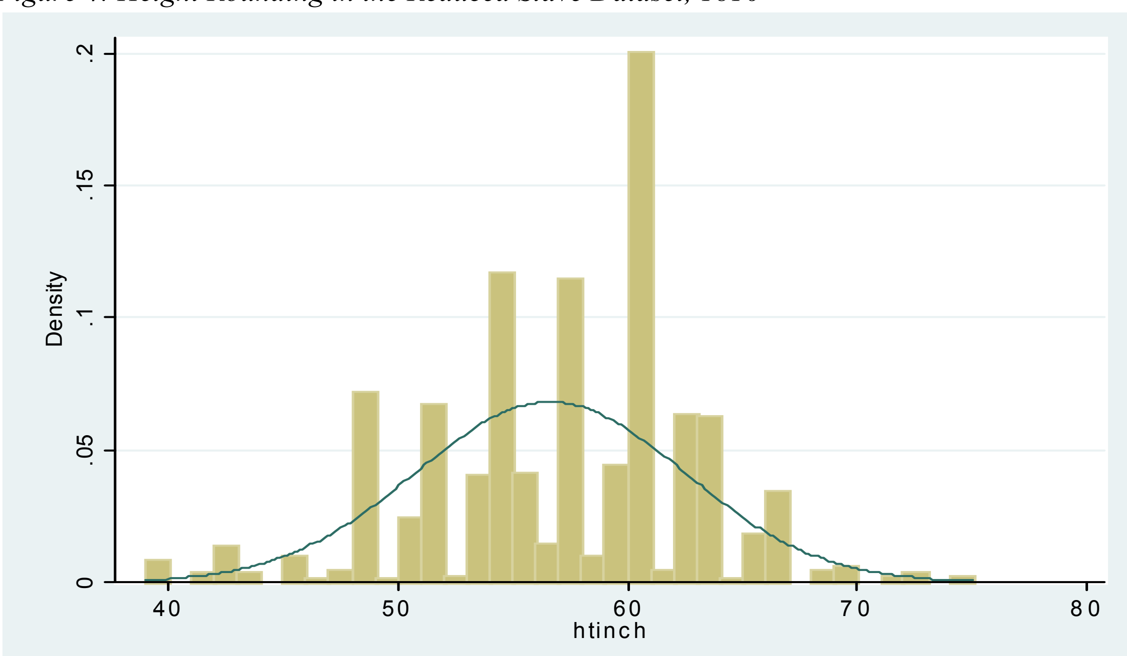


Figure 5: Histogram of Heights in the Migrant Dataset, 1888-1939

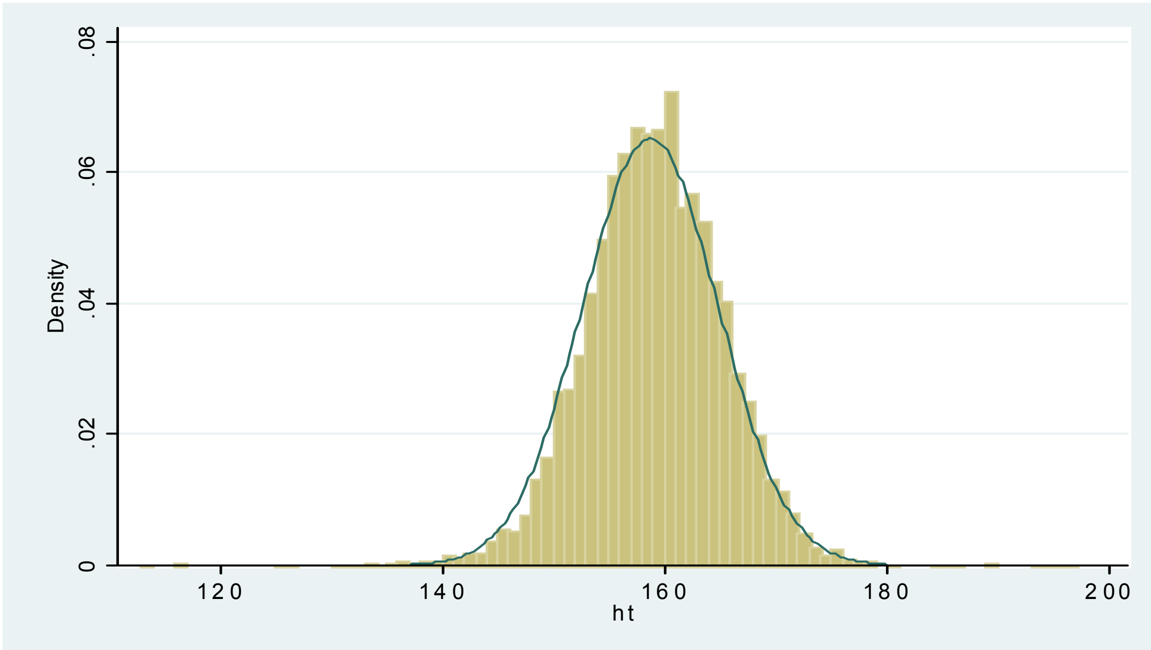


Figure 6: Height Trends of Adult Male and Female Migrants to Surinam by Birth Decade (centimeters)

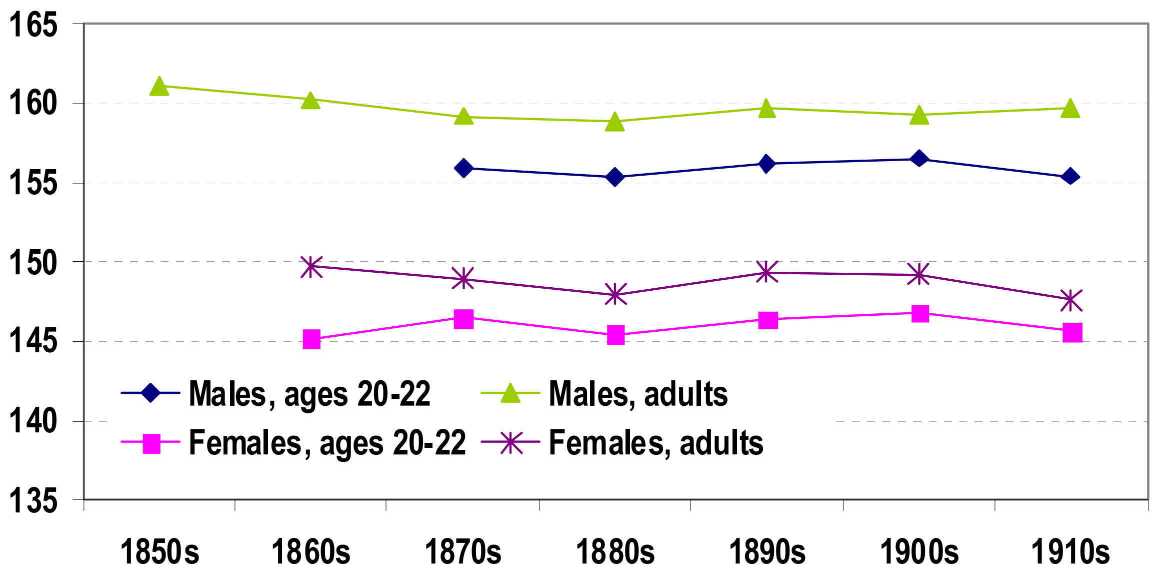


Figure 7: Histogram of Heights of Males from Anthropological and Medical Surveys

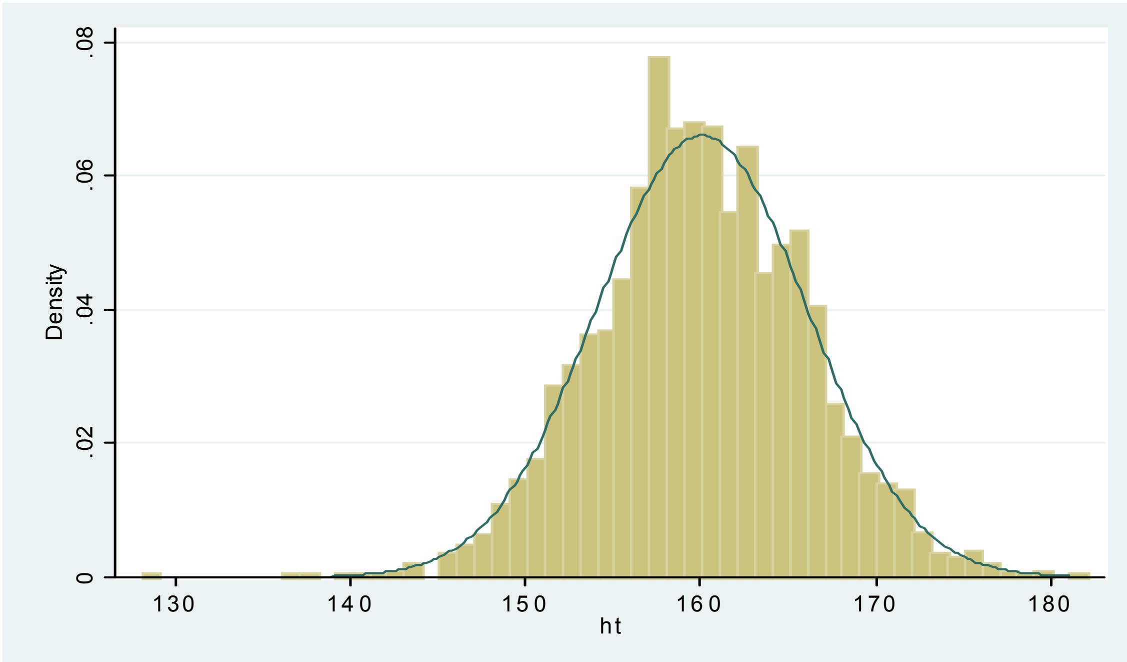
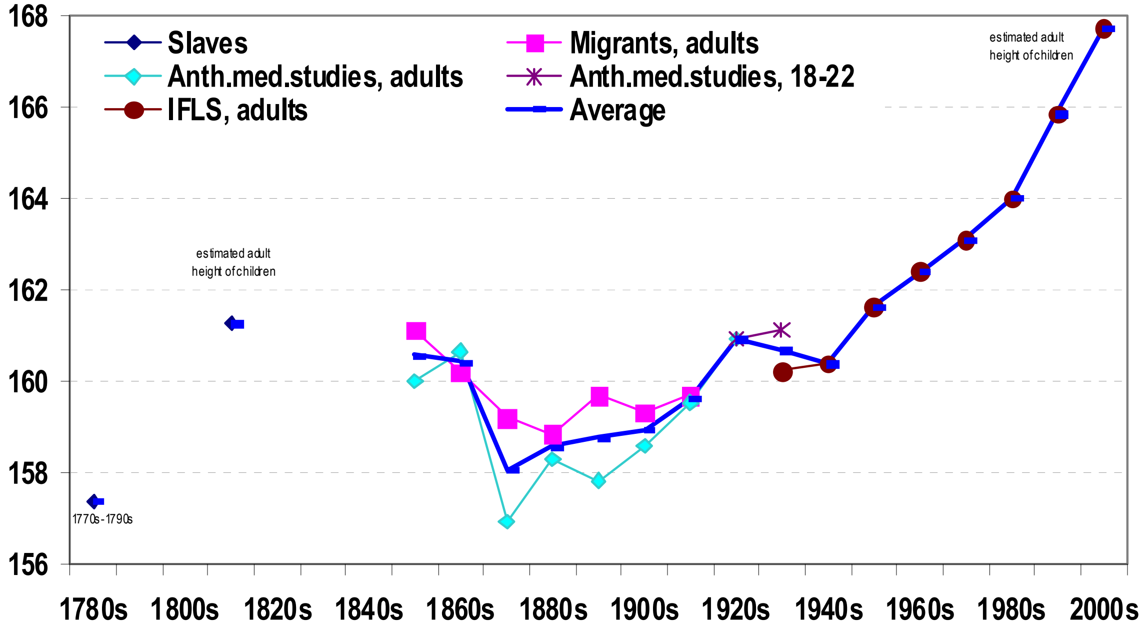
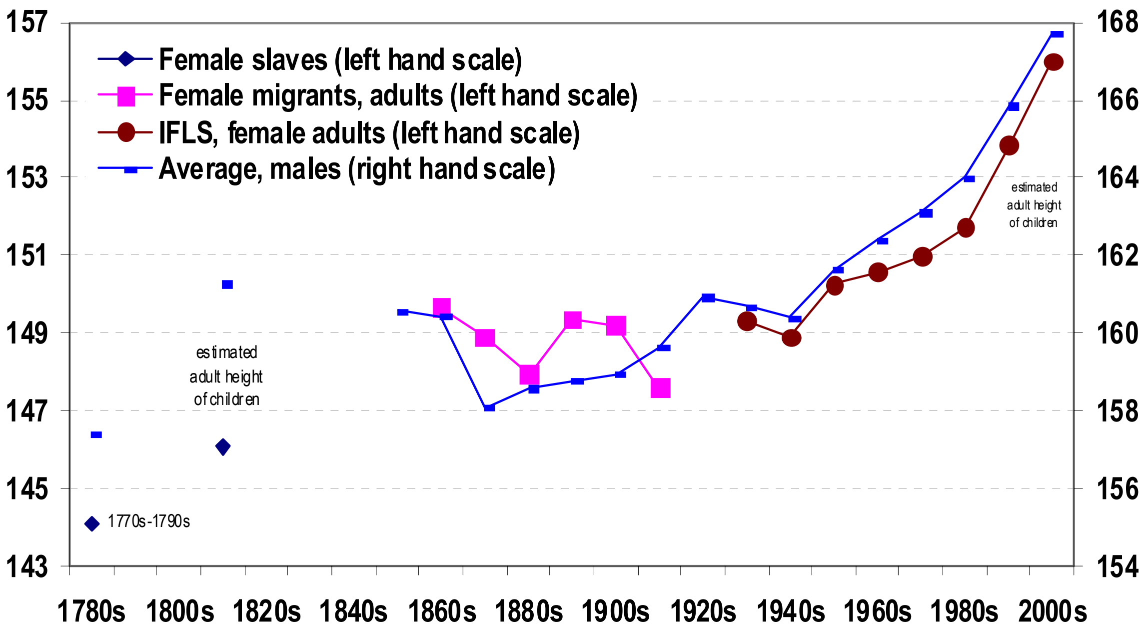


Figure 8: Average Male Height in Indonesia by Birth Decade, 1770s-2000s (centimeters)



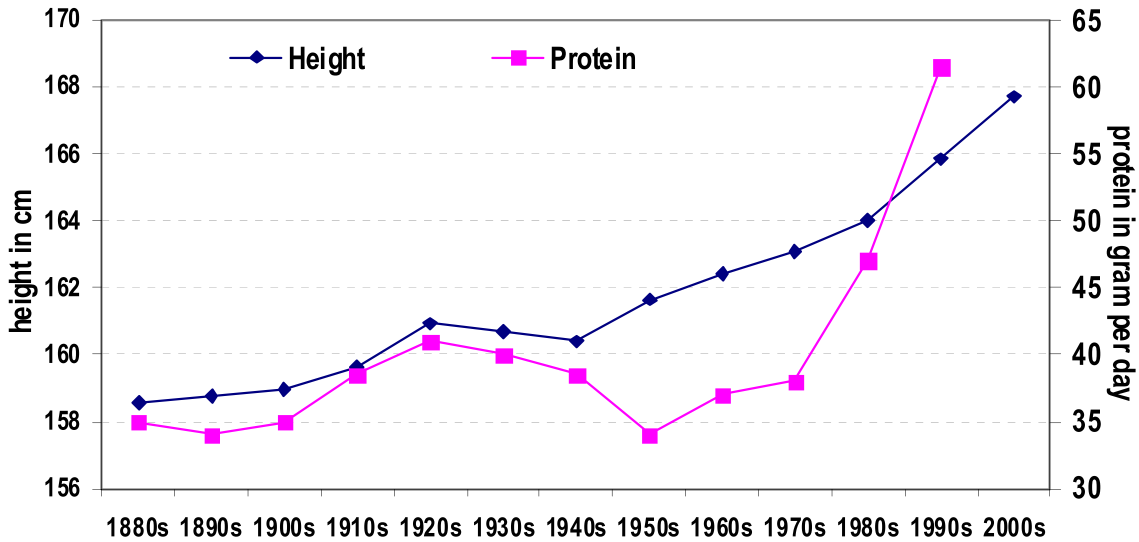
Notes: Birth decade 1780s refers to 1770s-1790s. For males aged 54-55 (birth decade 1930s) in the IFLS dataset, 1 cm was added to account for old-age shrinking.

Figure 9: Female and Male Height in Indonesia by Birth Decade, 1770s-2000s (centimeters)



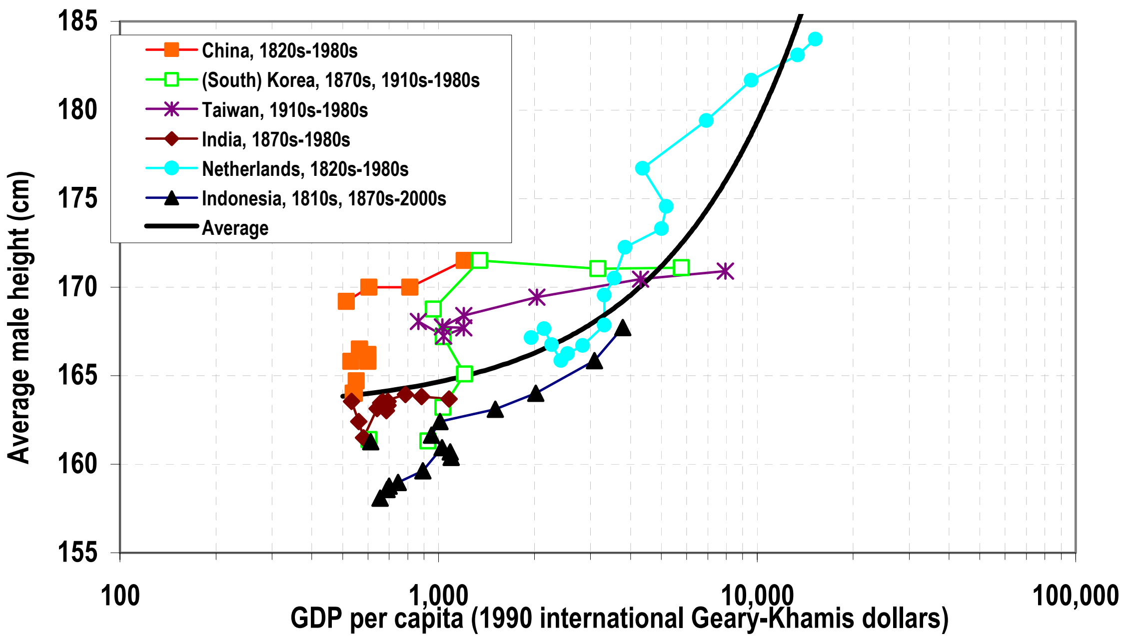
Note: Birth decade 1780s refers to 1770s-1790s.

Figure 10: Average Male Heights and Per Capita Supply of Protein, 1880s-2000s



Note: Heights by birth decade, per capita protein supply averaged by decade.
Sources: Figure 8 and Van der Eng 2000.

Figure 11: Heights of Adult Males and GDP per Capita, 1810s-2000s (decade averages)



Note: Heights by birth decade. Indonesia GDP per capita 1810s refers to 1820 only. Korea and India GDP per capita 1870s refers to 1870 only. Estimated average height = 163.016 + 0.00163116 × GDP per capita
Sources: Decade averages of male heights calculated from Figure 8 (Indonesia); Drukker and Tassenaar 1997 and Floud 1994 (The Netherlands); Morgan 2000 and Baten *et al.* 2010 (China); Kimura 1993 (Korea); Olds 2003, and Morgan and Liu 2007 (Taiwan); Brennan *et al.* 1994ab (India). The calculation method is explained in Baten (2009). Decade averages of GDP per capita from Maddison (2001), extended for Indonesia to 2008 based on Van der Eng (2010).

Table 1: Logistic Regression of Rounding on Full Foot Measures in the Slave Dataset, 1816

	value	p value
Female	-0.203	0.020
bdec1770	0.216	0.366
bdec1780	0.131	0.568
bdec1790	0.144	0.569
bdec1800	0.032	0.907
bdec1810	0.444	0.131
age15-16	-0.377	0.207
age17	-1.331	0.036
age18	-0.066	0.832
age19	-0.096	0.755
age20	0.137	0.615
age21	0.374	0.180
age22	-0.099	0.767
age51-55	0.566	0.102
age56-60	0.909	0.065
age61-65	-0.374	0.665
age66-70	0.514	0.719
Constant	-0.514	0.019
Number of observations	2,559	
Pseudo R-squared	0.01	

Note: All explanatory variables were included in the regression as dummy variables.

Table 2: Observations in the Reduced Dataset of Slaves Aged 20-55, 1770s-1790s

Birth decade	Males	Females
1770s	87	74
1780s	137	145
1790s	68	89
Total	292	308

Table 3: Regressions of Heights of Slaves Aged 20-55 by Region of Origin, 1816

	(1)	(2)
	Male	Female
Central Java	0.58	4.13
	(0.89)	(0.18)
Bali	-0.55	5.04**
	(0.82)	(0.05)
Southwest Sulawesi	0.68	1.30
	(0.71)	(0.53)
Aceh	-6.10**	-1.75
	(0.04)	(0.58)
East Nusa Tenggara	-0.73	5.78*
	(0.83)	(0.09)
West Nusa Tenggara	1.93	4.68
	(0.49)	(0.19)
age20-22	-0.73	-1.60
	(0.74)	(0.49)
Constant	157.39***	144.10***
	(0.00)	(0.00)
Observations	292	308
R-squared	0.02	0.03

Notes: All explanatory variables are included in the regression as dummy variables. p values are in parentheses. The constant refers to slaves born in Batavia (Jakarta).
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Observations in the Dataset on Migrants to Surinam, 1850s-1910s

Birth decade	Adult male	Male (18-22)	Adult female	Female (18-22)
1850s	54			
1860s	684	5	127	2
1870s	2,153	357	722	262
1880s	2,129	1,005	1,106	557
1890s	4,091	810	2,182	769
1900s	1,125	1,315	935	1,691
1910s	137	289	129	220
Total	10,373	3,781	5,201	3,501

Table 5: Regressions of Heights of Migrants to Surinam

	(1)	(2)	(3)	(4)
	Adult males	Males, aged 18-22	Adult females	Females, aged 18-22
bdec1850	1.82**			
	(0.031)			
bdec1860	0.88***		0.47	-1.60
	(0.0022)		(0.36)	(0.67)
bdec1870	-0.10	-0.58*	-0.31	-0.28
	(0.64)	(0.085)	(0.22)	(0.42)
bdec1880	-0.47**	-1.20***	-1.27***	-1.31***
	(0.029)	(0.00000066)	(0.000000041)	(0.00000048)
bdec1890	0.39**	-0.38	0.16	-0.41*
	(0.038)	(0.15)	(0.40)	(0.096)
bdec1910	-0.73	-1.12***	-1.60***	-1.13***
	(0.17)	(0.0082)	(0.0015)	(0.0071)
Jakarta	1.08***	1.14	1.33**	1.79**
	(0.0096)	(0.10)	(0.036)	(0.039)
Central Java	-0.29	-0.51	-0.16	0.40
	(0.33)	(0.22)	(0.69)	(0.35)
East Java	0.17	0.52	0.10	0.87*
	(0.59)	(0.24)	(0.81)	(0.063)
Yogyakarta	-1.10***	-0.56	-0.42	0.21
	(0.0011)	(0.26)	(0.35)	(0.66)
age51+	-1.35		1.19	
	(0.62)		(0.72)	
age18		-1.22***		-1.66***
		(0.00013)		(0.00000012)
age19		-0.47		-0.65**
		(0.12)		(0.023)
age21		1.20***		0.12
		(0.000050)		(0.66)
age22		1.55***		1.14***
		(2.3e-10)		(0.0000026)
Constant	159.32***	156.54***	149.21***	146.76***
	(0)	(0)	(0)	(0)
Observations	11,650	3,776	6,349	3,501
R-squared	0.01	0.05	0.01	0.04

Notes: All explanatory variables were included in the regression as dummy variables. The constant refers in all models to a person born in West Java during the 1900 birth decade. p values in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6: Observations in the Dataset from Anthropological and Medical Surveys

Birth decade	Adult males (23-55)	Males (18-22)
1850s	79	
1860s	250	
1870s	650	
1880s	2,936	
1890s	1,920	
1900s	4,753	
1910s	535	
1920s	1,050	732
1930s	22	1,288
Total	12,195	2,020

Table 7: Regressions of Heights of Males from Anthropological and Medical Surveys

	(1) Male adult	(2) Male age 18-22
bdec1850	1.42*	
	(0.07)	
bdec1860	2.06***	
	(0.00)	
bdec1870	-1.65***	
	(0.00)	
bdec1880	-0.29	
	(0.15)	
bdec1890	-0.77***	
	(0.00)	
bdec1910	0.95***	
	(0.00)	
bdec1920	2.33***	
	(0.00)	
bdec1930		0.21
		(0.88)
Central Java	-0.22	4.40**
	(0.41)	(0.01)
Bali	2.29***	
	(0.00)	
Central Kalimantan	-0.34	
	(0.51)	
Nusa Tenggara	-1.78***	
	(0.00)	
North Sulawesi	-0.55	
	(0.20)	
North Sumatra	2.69***	3.49
	(0.00)	(0.22)
West Nusa Tenggara	1.39***	
	(0.00)	
West Sumatra	-0.42	
	(0.19)	
Yogyakarta	2.81***	
	(0.00)	
age1819		-2.38*
		(0.06)
age2021		-4.24**
		(0.04)
Constant	158.60***	159.10***
	(0.00)	(0.00)
N(Original)	12,195	2,020
R-squared	0.25	0.92

Notes: All explanatory variables are included in the regression as dummy variables. The constant of the regression of adult height refers those born in 1900s in West Java. The constant of the regression of adults aged 18-22 refers those born in the 1920s in West Java, aged 22. N(Original) refers to the underlying, originally measured persons. The number of different height figures (counting grouped data as 1) is 2,155 for the males and 10 (grouped data) for the age 18-22 column.

Table 8: Observations in the IFLS Datasets for 1993, 2000 and 2007 (ages 23-55)

Birth decade	Male adults	Female adults
1930s	82	81
1940s	1,103	1,257
1950s	1,767	1,959
1960s	1,930	2,428
1970s	1,255	1,188
1980s	194	249
Total	6,331	7,162

Table 9: Regressions of Heights from the IFLS Datasets for 1993, 2000 and 2007

	(1) Male Adults	(2) Female Adults
bdec1930	-3.87***	-2.66***
	(0.000000017)	(0.000024)
bdec1940	-2.71***	-2.09***
	(0)	(0)
bdec1950	-1.46***	-0.73***
	(1.2e-10)	(0.00036)
bdec1960	-0.70***	-0.40**
	(0.0015)	(0.040)
bdec1980	0.90*	0.75*
	(0.059)	(0.060)
North Sumatra	0.19	-0.12
	(0.58)	(0.68)
West Sumatra	-0.82**	-0.67**
	(0.038)	(0.045)
Bali	1.04***	2.24***
	(0.0062)	(0)
Central Java	-1.33***	-0.52**
	(0.0000029)	(0.031)
East Timor	-0.46*	-0.36
	(0.089)	(0.12)
Jakarta	0.34	0.26
	(0.27)	(0.33)
Lampung	-1.21***	-0.80**
	(0.0036)	(0.031)
Riau	4.27**	0.72
	(0.033)	(0.79)
South Kalimantan	-1.72***	-1.42***
	(0.000015)	(0.000081)
South Sulawesi	0.05	0.54*
	(0.90)	(0.096)
South Sumatra	-1.02**	-0.16
	(0.015)	(0.65)
West Nusa Tenggara	-1.20***	-0.64**
	(0.0011)	(0.047)
Yogyakarta	-0.17	0.62*
	(0.66)	(0.061)
Constant	163.11***	150.99***
	(0)	(0)
Observations	6,331	7,162
R-squared	0.04	0.03

Notes: The explanatory variables were included in the regression as dummy variables. The constant of the regression of adult height refers those born in 1970 in West Java. The p values are in parentheses. *** p<0.01, ** p<0.05, * p<0.1