Indonesian regional welfare development, 1900-1990: New anthropometric evidence[1]

By Péter Földvári (University of Debrecen), József Gáll (University of Debrecen), Daan Marks (Utrecht University) and Bas van Leeuwen (Free University/Utrecht University/Warwick University)

ABSTRACT

The study of heights provides a promising approach to a better understanding of the biological welfare of countries and regions for which conventional economic data are relatively sparse. This paper is based on a dataset previously unexploited: the individual records of nearly 10,000 Indonesian men conscripted into the Royal Netherlands East Indies Army (KNIL) used together with individual data on another 10,000 Indonesians, recorded as part of the Indonesian Family Life Surveys (IFLS). These two sets of records provide the height and place of birth of members of birth cohorts spanning nearly the entire 20th century.

Our aim in this paper is to trace the development of average height in Indonesia over the course of the twentieth century. Whereas both average height and average income increased during the second half of the century, we find that this was only after they had diverged in the first half: a divergence similar to the one (frequently discussed in the literature) that had occurred in several other countries toward the end of the 19th century. Using a newly developed "height accounting" method, we estimate that in Indonesia increasing income inequality accounts for about half of this divergence, which gradually disappeared after the Second World War, as income inequality decreased and average height increased until it was rising in tandem with average income.

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1. Introduction

The notable increase over the past several years in the number of anthropometric studies devoted to economic development (Komlos, 1998; 2004; Stegl and Baten, 2009) reflects the emerging consensus among anthropometricians that height is indicative of an individual's economic - and nutritional environment at birth (Tanner, 1978; Steckel, 1995). One significant advantage of the anthropometric approach is that it provides a measure of the standard of living in regions and periods for which conventional economic data are lacking. Take, for instance, the case of Indonesia; because the data on economic and social conditions there prior to 1993 are inadequate (Van der Eng, 2002), researchers lack the means to resolve satisfactorily their debate on the issue of welfare development (Booth, 1998; Dick et al., 2002), and especially of the impact of the government's so-called "ethical" policy during the first half of the 20th century, deemed (depending upon what indicator was used) a success by some (e.g., Boomgaard, 1986; Van Doorn, 1994) and a failure by others (e.g., Elson, 1984; Barlow, 1985). The room for debate widens when one turns one's attention to regional development (Clemens and Lindblad, 1989). Height-development data on Indonesians provide a reliable basis for measuring variations in their biological welfare across both time and space.

The fact that the relationship between income and height is non-monotonous -- that a rise in average income is often accompanied by a stagnation, or even a decline, in average height -- is an issue familiar to readers of the literature. It underlies the Antebellum Puzzle in the US (Komlos, 1987) and the Food Puzzle in Great Britain (Floud, Wachter, and Gregory, 1990; Clark, Huberman, and Lindert, 1995) and recently also in Burma (Bassino and Coclanis, 2008). This seesaw phenomenon is usually, but not exclusively, attributed to the geographical separation, beginning in both countries in the late 19th century, between the place of food production (agricultural regions) and the bulk of the food's consumers (urban regions); the nutritional quality of one's diet becomes a function of geography.

Above line of reasoning suggests that the several factors separating persons from food consumption led to increasing height inequality in the 19th century. However, this argument will only apply if per capita income is sufficiently low since with higher incomes also consumption will be higher. Indeed, Steckel (1995) argues that in phases of economic development marked by a low per capita GDP, height changes are largely attributable to an increase in income equality. When per capita GDP reaches a sufficiently high level, further changes in height are driven by economic growth.

Our purpose in this paper is to determine whether this pattern, describing the economic evolution of the US and Great Britain, holds for an underdeveloped country, namely Indonesia. In order to try to determine whether height changes in the early phase of economic development were driven by one set of forces and in a later phase by others, and what those forces were, we construct a height dataset, paying particular attention to differences between Java and the Outer Provinces (everything outside of Java, i.e. including the main islands of Sumatra, Kalimantan, Sulawesi, and Irian Jaya). We then use both qualitative data and a method of height decomposition in order to account for changes in average height.

The paper is organized as follows. In Section 2 we describe the data and report some descriptive statistics. In Section 3 we explore the relationship between height and income in Indonesia, and address the issue of whether evidence for this relationship can be found in food consumption and health. In order to determine whether height changes during the 1930s were due to one set of factors and postwar ones to another, we decompose, in Section 4, the observed height changes into a level effect and a distribution effect of income, on the one hand, and a residual factor, on the other. Finally, we offer our conclusions.

2. Height data for Indonesia

Because there is little extant information on income inequality in developing countries prior to the

1950s, those who study this issue draw instead on anthropometric data.[2] Notable among such studies are those of Komlos (1985) and Austin, Baten, and Van Leeuwen (2011), and in the case of Indonesia in particular Van der Eng (1995) and Baten, Stegl, and Van der Eng (2010).

In the latter study the development of heights in Indonesia between about 1750 and 1990 is estimated on the basis of four sources: slave data, migrant data, medical/anthropometric studies, and a recent dataset derived from the Indonesian Family Life Survey (IFLS), for the birth cohorts that span the period 1940-90. For information on height changes during the first half of the twentieth century, they rely on several medical/anthropometric studies. While these sources shed some light on the overall development of height within Indonesian society, the data themselves are drawn from heterogeneous sources. Moreover, the authors do not deal with the difference between Java and the Outer Provinces, an issue that is frequently discussed in the literature. In order to address this difference, we use a newly available dataset for the period 1900-30 which, while less than perfect, is internally consistent and thus permits us to examine the issue of interregional development in the first decades of the twentieth century. Using another, equally consistent, dataset on heights after the 1930s we are able to analyze height trends over the entire twentieth century.

The first source consists of military data -- name, age, place of birth, and height -- on 9,085 Indonesian men born between about 1890 and 1935 who joined the Dutch forces between 1945 and 1947. (Although the original muster rolls are missing, these data are preserved in military-pension documents housed in the national archives.) Most of the birth years are located between 1900 and 1930 (Table 1 and 2).[3] Our other source consists of two Indonesian Family Life Surveys (IFLS-1

[2] An exception is Baten et al. (2009), but it is on the basis of anthropometric data that they estimate many of their Gini coefficients.

[3] The rapid deterioration of the Dutch position in Indonesia after the Second World War raises questions about the geographic heterogeneity of our dataset. While a large proportion of the Dutch soldiers reenlisted after the war, because of the unstable situation, including the British occupation of Java, most of the new recruits came from North Sulawesi, the Moluccas, Timor, and West Java (Zwitzer and Heshusius, 1977). Our dataset does indeed slightly reflect this regional bias: the percentage of recruits from these areas rises from about 45% before the war to about 58% after the war. Moreover, men from the island of Madura constituted a disproportionately large number of the postwar recruits (Bouman, 1995), a disproportion reflected in our dataset, which includes -- in addition to standard numbers of recruits from the other regions of Indonesia (2,168 Javanese, 1,632 Manadonese, 1,135 Ambonese, 1,751 Sundanese, and 270 Timorese) -- 447 Madurese, a significantly higher percentage than in 1937.

In other words, we found an increase in the proportion of recruits from regions other than the island of Java in the postwar period. This phenomenon improves the quality of our dataset for two reasons. First, it makes for a wider and -4), those for 1992 and 2007, which contain the same sort of information on Indonesians born between 1930 and 1990 (see Frankenberg and Thomas, 2000; Strauss et al., 2009).

The problems associated with using military data to derive an overall in population development have been reviewed by Komlos (2004). Since military recruits are obviously a very selective source, it is most probably notpossible to estimate the average height estiamtes of the Indonesian male population from this sample. However, it is possible to derive a general height trend or at least the direction of changes in heights. Hence, in the remainder of the paper we keep the IFLS (which contains an average sample of the entire population) and the military sample separate and focus only on the trends in heights.

In order to make the trend in our military recruit data representative for the development of height in the general population, we are obliged to make three adjustments, to avoid three potential problems.[4] The first problem is that of age truncation: Because the military recruits ranged in age from their 20s to their 50s (a few persons born in 1929 and the 1930s were 16-18 years of age but these were not used in the analysis in the next Sections), with the majority in their 20s and 30s, we excluded IFLS data below age 20 and over age 60, so that the two sets would match. As Guntupalli and Baten (2006) observe, 20 is the appropriate minimum age, since it is the age at which growth of any significance ceases. Complicating the issue is evidence that an individual's maximal height is followed by a more or less slight decline at older ages (Galloway, 1988; Cline, Boyer, and Burrows, 1989; Chandler and Bock, 1991), which is offset by the fact that longevity is correlated with nutrition, and therefore with health and indirectly with height.

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geographical representation, correcting the prewar bias in favor of the Moluccas and Java. Second, it provides a more accurate cross-section of the population -- its religious, educational, and occupational makeup -- since it was not until the war that men from a wide range of social strata were able to enlist. In fact, when it comes to occupations our sample's figures come close to matching those of the censuses (i.e. 71, 9, and 20 percent for agriculture, industry and services in our sample versus 67, 12, and 21 percent for Indonesia as a whole [Marks, 1992]). This also applies if we only look at the older age cohorts, suggesting that there is no evidence of any serious bias in that older soldiers have higher ranks and originate from more wealthy families.

[4] Besides these three problems, we also had to deal with two other questions. First, since the pre-War data are for military recruits, this implies we have only data for males. Therefore, we only take male data from the IFLS. Second, IFLS 1 and 4 have been combined by taking men between ages 20 and 60 that do not overlap. Since the IFLS is a survey in which the same persons return in subsequent surveys, we only include persons once. If they had children below age 20 in the 1993 survey, we did not include those. If the same children showed up in the 2007 survey and they were older than 20 years, we did include them. The same applies to people that entered the survey in 2007 in split-off households (i.e. a husband or wife of someone in the household survey of 1993).

Since these studies of age-height correlations are based on European data, one might well doubt that they apply to developing countries, but Morgan (2010) using a sample of Chinese migrants in Australia concluded that ethnicity is not a significant factor in the phenomenon of old-age shrinking; his finding that up to the age of 60 shrinking amounted to no more than about 1 cm corroborates that of Cline, Boyer, and Burrows (1989). We therefore accept the advice of Baten, Stegl, and Van der Eng (2010) and add 1 cm to the heights of those in the IFLS sample above the age of 54 (i.e., the 1930s birth cohort).

The military data reveal a significant shift in the distribution of heights during the late colonial period, with an increasing proportion of the Indonesians under study measuring between 150 and 164 cm in height, which implies on average a decline in height in our total sample. After 1930, based on the IFLS data, we may witness a changing trend: the percentage people in the tallest height categories increases substantially, signaling an increase in average height in the population in Indonesia from the 1930s onwards (see Table 1). Yet, not only the trend in average height changed over time, Table 2 also shows that prior to the 1930s heights are skewed to the right (indicating a decline in nutrition for the economically weakest) while in the postwar period they

Table 1
Distribution of Indonesian conscripts by height intervals and birth years in 1895-1928 (military) and 1935-85 (IFLS)

Source	No. Observations	year	Height in cm >166	>164	>158	>155	>150	<150
National Archive	65	1890-1899	16.9%	23.1%	35.4%	10.8%	7.7%	6.2%
	82	1900-1909	25.6%	26.8%	24.4%	4.9%	7.3%	11.0%
	1,310	1910-1919	20.7%	24.9%	29.9%	10.2%	4.7%	9.7%
	6,382	1920-1928	15.3%	22.2%	31.9%	12.5%	6.4%	11.6%
IFLS	871	*1930-1939	11.7%	17.1%	27.7%	10.0%	5.4%	28.0%
	1,058	1940-1949	15.5%	20.2%	28.3%	8.7%	6.0%	21.3%
	1,571	1950-1959	19.7%	24.7%	27.3%	8.1%	5.3%	15.0%
	1,289	1960-1969	20.6%	25.9%	27.0%	7.1%	5.3%	14.0%
	3,527	1970-1979	30.4%	27.0%	22.8%	6.3%	3.1%	10.5%
	2,877	1980-1989	34.9%	28.0%	21.3%	4.9%	2.5%	8.4%

*The IFLS data for persons above the age of age 54 (i.e., the birth cohort 1930-40) are increased by 1 cm.

Table 2

Summary statistics by birth year

	no. observations	mean	std dev.	skewness
		Military data		
1890-1899	65	162.2	5.2	0.645
1900-1909	82	162.9	5.8	0.441
1910-1919	1,310	162.3	5.5	0.434
1920-1928	6,382	161.3	5.0	0.464
		IFLS		
1930-1939	871	158.2	6.2	0.105
1940-1949	1,058	158.3	6.5	-1.160
1950-1959	1,571	159.3	5.8	-0.055
1960-1969	1,289	160.4	6.0	-0.246
1970-1979	3,527	162.1	6.3	-0.826
1980-1989	2,877	162.7	6.3	-0.817

are skewed to the left.

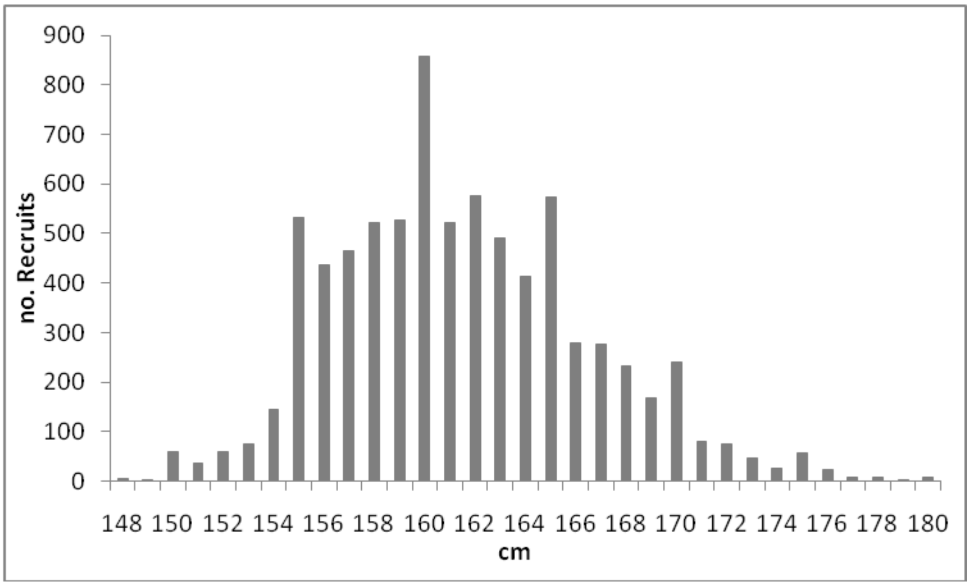
The second potential problem is that of height truncation. Because the military data are truncated and the IFLS data are not -- the truncation accounting for the smaller proportion of heights under 145 cm in the former than in the latter -- one needs to find a way to correct for the omission of people with lower heights in the military data (see Appendix). The reason is that, since there is a minimum-height requirement for enlistment, statistical analysis of military-recruitment data is likely to lead to biased results.

There is good reason, however, to think that in Indonesia the government was more lenient with the minimum-height requirement for Indonesian soldiers: for instance, it began at 162 cm for Dutch (and Ghanaian) soldiers in the Royal Dutch Indies Army (Austin, Baten, and Van Leeuwen, 2011), whereas the truncation point in our sample of Indonesian recruits appears to be 145 cm (Figure 1). This means that people with heights lower than 145 cm (i.e. the data are left truncated) were in principle not recruited.[5] However, when data is left-truncated the sample mean

[5] The official truncation point (minimum length requirement) is unknown. The majority of the reruits were above

overestimates the population mean and the sample variance underestimates the population variance. The most

Figure 1: Height distribution of Indonesian recruits born between 1890 and 1928



Source: This text

common method to correct for this bias is to assume that the distribution of heights is normal and use a modified likelihood function when estimating the population moments. This method is valid in the case of most present-day samples but not those from periods when most of the population lived near the subsistence level and even minor fluctuations may have a significant impact on nutrition and therefore height (A'Hearn, Peracchi, and Vecchi, 2008), i.e. if the height distribution is positive skewed (see Table 2). Indeed, in the case of Indonesia in the 1930s it has been estimated (Van Leeuwen and Foldvari, 2012) that over 65% of the population were living at the poverty line, set by the World Bank, of 1 USD/day (or 2 USD, if one uses survey data), which makes a strong positive skew in heights likely. For this reason we use a 3 parameter skew-normal (SN) probability distribution, which will capture the asymmetry of the height distribution when correcting for truncation (Appendix; see also O'Hagan and Leonhard, 1976, and Azzalini and Capitanio, 1999).

The third and final problem is that the regional percentages of recruits may change over time

155cm but possibly the recruitment boards were not very strict in this sense and recruited people above 145 cm as well. This length seems to be the practical truncation point.

(as we report in footnote 3); fortunately, we find little evidence of such a change in the case of our sample, although there are some minor shifts in the geographic spread. For example, the percentage of recruits from Java rose from 50 to 60 between 1900 and 1910. When average height varies from region to region, such an increase from one region can, of course, be a problem. This is true even when we assume that income is the same across regions, and there is little if any correlation between ethnicity (which is correlated with region) and height, because there remains the effect of regional (and by extension cultural) differences in diet. For example, Holleman, Koolhaas, and Nijholt (1939) found that the diet of the Chinese who live on Jakarta and Sumatra, Indonesia differs significantly from that of the Javanese. Holleman et al. show that in the 1930s the Chinese in Batavia consumed on average 48.7 g of protein and a total of 1,448 kcal. daily, whereas the Javanese (whose diet was largely vegetarian) consumed less protein (40.2 g) but more calories (1,520) (Table V). Since protein is directly correlated with growth (Steckel, 1999), one would expect these Chinese to be on average the taller of the two groups. Indeed, in our dataset the

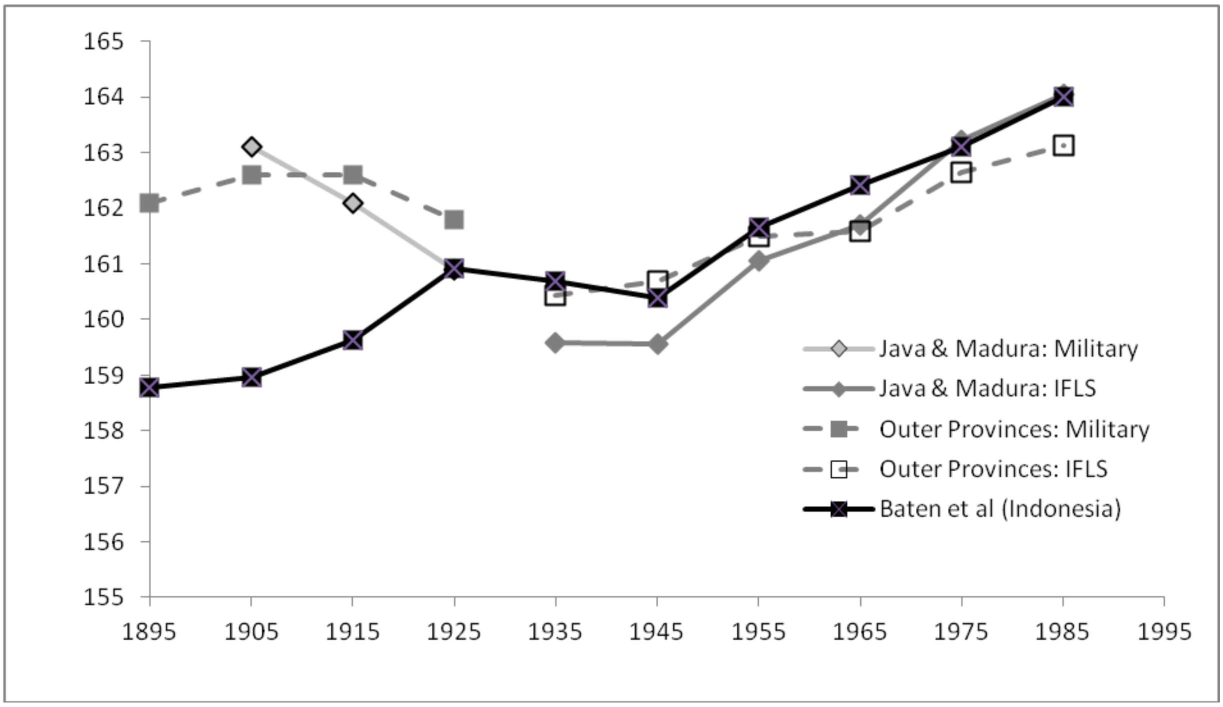
Table 3

Height of men in Indonesia by birth year

	This text				Baten, Stegl, and Van der Eng
	Java & Madura	Outer Provinces	Height Java-height Outer Provinces	Indonesia	Indonesia
		Military recruits			
1890-1899	160.9*	162.1	-1.2	161.5	158.8
1900-1909	163.1	162.6	0.5	162.9	159.0
1910-1919	162.1	162.6	-0.5	162.3	159.6
1920-1928	161.4	161.9	-0.5	161.3	160.9
		IFLS data			
1930-1939	159.6	160.4	-0.8	159.9	160.7
1940-1949	159.6	160.7	-1.1	160.1	160.4
1950-1959	161.1	161.5	-0.4	161.2	161.1
1960-1969	161.7	161.6	0.1	161.6	162.4
1970-1979	163.2	162.6	0.6	163.0	163.1
1980-1989	164.1	163.1	1.0	163.8	164.0

Note: IFLS data for persons above the age of 54 (i.e., the birth cohort 1930-40) are increased by 1 cm.
* based on 15 observations, caution is advised

Figure 2: Height (cm) by birth year, 1895-1985



Source: Baten, Stegl, and Van der Eng (2010) and this text.

Chinese had a height advantage of almost 1 cm over Indonesians in general and of 2 cm over the Javanese, thereby obliging us to add a variable capturing regional/ethnic percentages.

Two separate but related trends in height emerge from our data for Java and Madura, the Outer Provinces, and Indonesia (Table 3 and Figure 2). First, while they move in line with those of Baten, Stegl, and Van der Eng (2010), ours indicate first stability followed by a modest decline between about 1915 and 1928, whereas theirs indicate a substantial increase.[6] Second, we find that heights on Java are consistently lower than those in the Outer Provinces from 1910 until about 1965, when this pattern is reversed.

3. Explaining height development in Indonesia

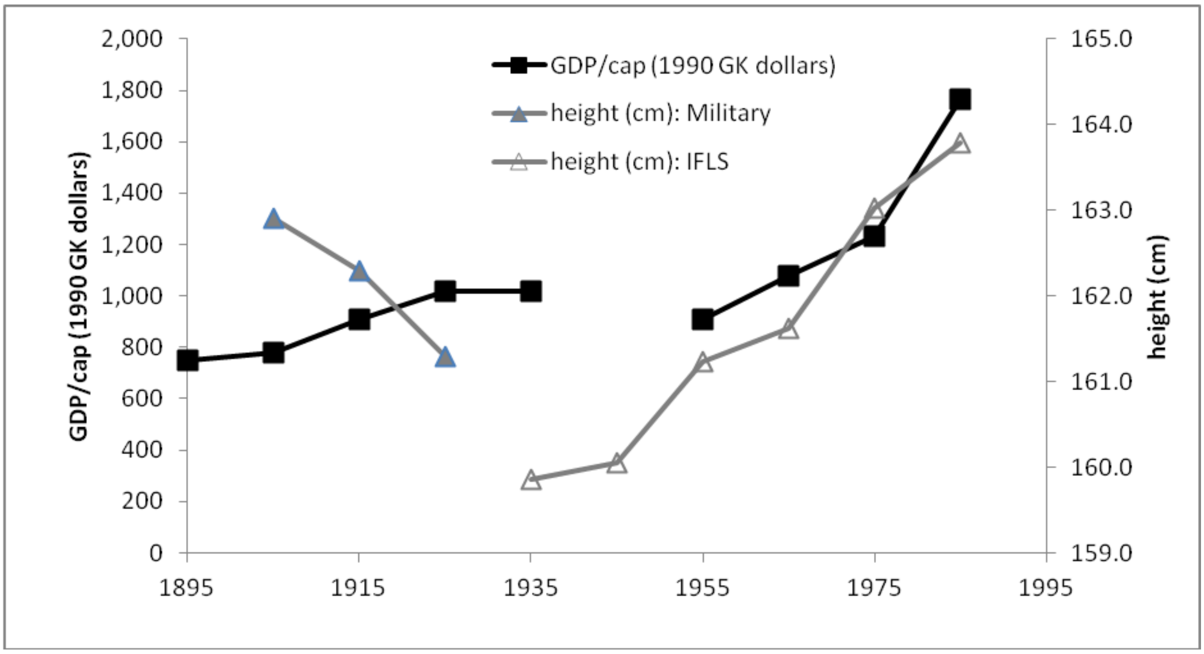
We find that height averages in Indonesia were stable, or decreased only insignificantly, between about the mid-1910s and 1930, and then declined sharply during the economic crisis of the 1930s and during the war, after which height on Java increased steadily, outpacing the increase in the

6 We confirmed our results with a cross-check: a standard truncated regression that corrected for birth region and ethnicity and derived the height trend by means of time dummies.

Outer Provinces.[7]

As Baten, Stegl, and Van der Eng (2010) emphasize, thanks to improvements in diet and/or health generally, these data are correlated, if imperfectly, with per capita GDP. It is therefore surprising to note that until the 1930s per capita GDP was rising but heights were either on a plateau

Figure 3: Height and GDP/cap comparison by birth year for Indonesia



Source: Maddison (2007), BPS (2010), and this text.

or, in some regions, on a downward slope. Indeed, it is not until about 1950 that the correlation between per capita GDP and height is consistently positive (Figure 3).

Following Steckel (1995) and Bassino (2006) we estimate the relation between height and income as

$$h_i = \alpha + \beta \ln y_i + \sum_{j=1}^{p} \gamma_j X_{j,i} + u_i \tag{1}$$

where *h* and *y* denote height and some measure of per capita income, respectively, and *X* denotes other exogenous variables (geographical, social factors, etc.), while *u* is an error term

[7] Due to the limited number of observations, we'd rather not draw conclusions regarding height trend from the subsample of recruits born before the 1910s.

($u \sim iid(0, \sigma_u^2)$). We use data from Sumatra, what we term "Other Outer Provinces," and four regions of Java: West Java, Central Java, East Java, and Batavia (present-day Jakarta). Height data are derived from our dataset as we described in the previous section. As for income, we use data on unskilled labor from Dros (1992) for the period up to 1940. Badan Püsat Statistik (BPS), a non-departmental governmental service, provided data on per capita GDP (excluding oil and gas revenues) for 1971, 1980, and 1990. This means that we have a different income measure before 1950, while also the level of height might have a different before 1930 since it is based on military data. Hence, we include a dummy to capture the level difference of the military data, and a dummy as well as a cross effect between the wage dummy and lnwage to capture the level difference of the use of wage data instead of GDP per capita. The regression analysis indicates that over the course of the entire 20th century the logarithm of per capita GDP affected height by a factor of 1.41 (Table 4); that is, for every percentage increase in income, average height increased by 1.41 mm, whereas Bassino (2006) estimated a coefficient of between 1 and 3 mm for Japan. Such a wide gap between Indonesia and Japan is surprising, especially because Indonesia is poorer than Japan; one possible explanation is that Bassino based his calculation on per capita income, whereas we

Table 4

Regression results (equation 1)

Dependent variable: height (cm)		
	Spec1	Spec 2
Constant	152.68 (41.43)	152.57 (43.88)
Ln GDP/cap	1.41 (3.11)	1.45 (3.36)
D lnwage	-33.32 (-2.61)	-19.00 (-1.34)
Ln GDP/cap*D lnwage	3.82 (2.29)	2.08 (1.14)
D military	2.02 (3.93)	2.48 (4.57)
D Central Java	0.62 (0.94)	1.37 (1.86)
D East Java	0.68 (1.07)	1.79 (2.14)
D West Java	1.06 (1.65)	1.47 (2.27)
D Sumatra	-0.94 (-1.68)	0.10 (0.13)
D "Other Outer Provinces"	-0.18 (-0.30)	1.18 (1.28)
"share of population working in agriculture"	-	-0.04 (-1.89)
R2	0.821	0.848
N	31	31

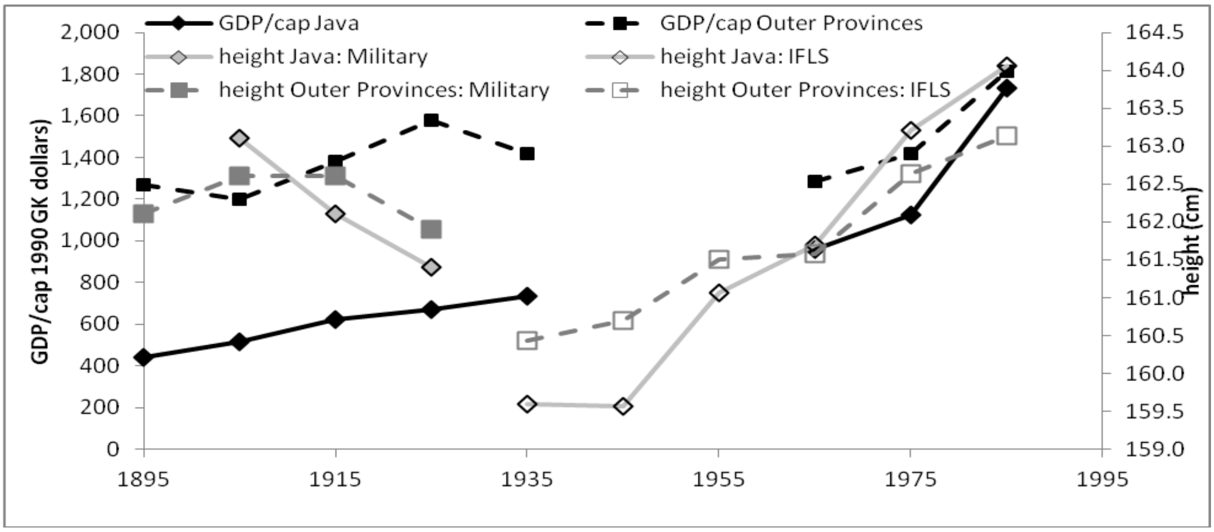
Note: Robust t-statistics are reported in parentheses.
Note: Since before 1930 we use military height data and combined with wage data, the cross effect picks up both effects.
Source: GDP per capita data (only for benchmark years) taken from the Badan Püsat Statistik (BPS) (www.bps.go.id) for 1971, 1980 and 1990. Wages by region taken from Dros (1992)

used per capita GDP. If we use wages the coefficient becomes 1.41+3.82=5.23, which is close to the coefficients (4.9 for adolescents, 3.97 for adults) found by Steckel (1995). Not surprisingly, there is a stronger relationship between height and unskilled wages than between height and per capita GDP. The only region where the average height is not in line with that of Jakarta is Sumatra, where, even when one captures the effect of lower income, average height is inferior by 0.94 cm.

Since it is common to correct height development for differences in health situation, we need to find an indicator that captures health differences. One possibility is the "share of population working in agriculture" since it is commonly assumed that people in the city suffer from adverse living conditions and thus have a worse health.[8] Adding this variable in specification 2 (Table 4) it yields a negative coefficient. That this coefficient is negative is a bit surprising. However, especially in the latter part of the century people in the countryside were considerably poorer than in the cities. On average, however, the effect on height is small indicating that the direct effect of health on height is limited, at best. Indeed, health tends to improve only gradually (Baten, Stegl, and Van d er Eng, 2010) and therefore cannot by itself account for the height increase that marked the 20th century.

Van der Eng (2002), Van Zanden (2002), and BPS (2010) provide us with the figures for the per capita GDP (abbreviated as "GDP/cap" in our tables and figures) for both Java and the Outer Provinces, which, once converted to 1990 GK dollars (Geary-Khamis international dollar), is plotted in relation to height (Figure 4) which is obtained using the method described in the

Figure 4: Height and per capita GDP for Java and the Outer Provinces by birth year



Source: Van Zanden (2002) ; Maddison (2007).
Note: Per capita GDP from 1960 on excludes oil and gas income.

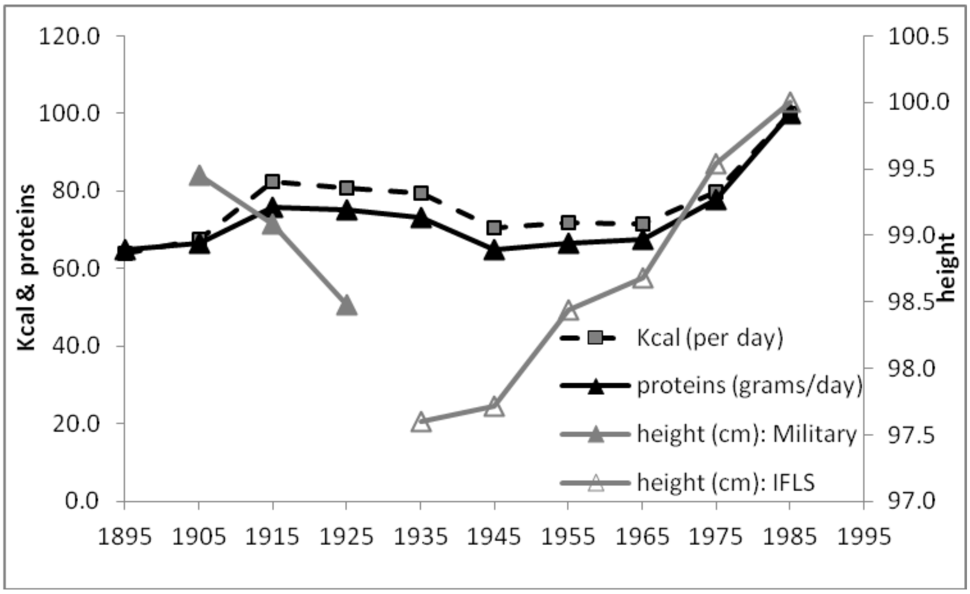
appendix. Per capita GDP proves to be stable both on Java and in the Outer Provinces until the 1930s, when heights decrease. It is only after the war that a clear correlation between per capita GDP and average height appears in both regions, both of them being higher in the Outer Provinces

[8] A similar method is applied by Bassino (2006). Likewise, we also include region dummies which not only capture health but also differences in workload.

than on Java until 1955, at which point they continue to increase on Java, whereas both stagnate in the Outer Provinces.[9] By about 1990, per capita GDP (excluding income from oil and gas) on Java exceeded per capita GDP in the Outer Provinces. That Java would take the lead thus was predictable on the basis of just one biological measure of the standard of living: by 1965 average height on Java already surpassed that recorded in the Outer Provinces.

Not only do Java and the Outer Provinces thus converge when it comes to both per capita GDP and heights; in the first half of the twentieth century both of them combine a rising per capita GDP with stable or declining heights, raising the question, what drove the height increases? The answer that springs to mind is based on the direct correlation, often mentioned in the literature (e.g. Steckel, 1995), between income growth and protein and calorie intake, and between protein and calorie intake and an increase in average height.

Figure 5: Proteins & kcal supply per day and heights by birth year (1985=100)



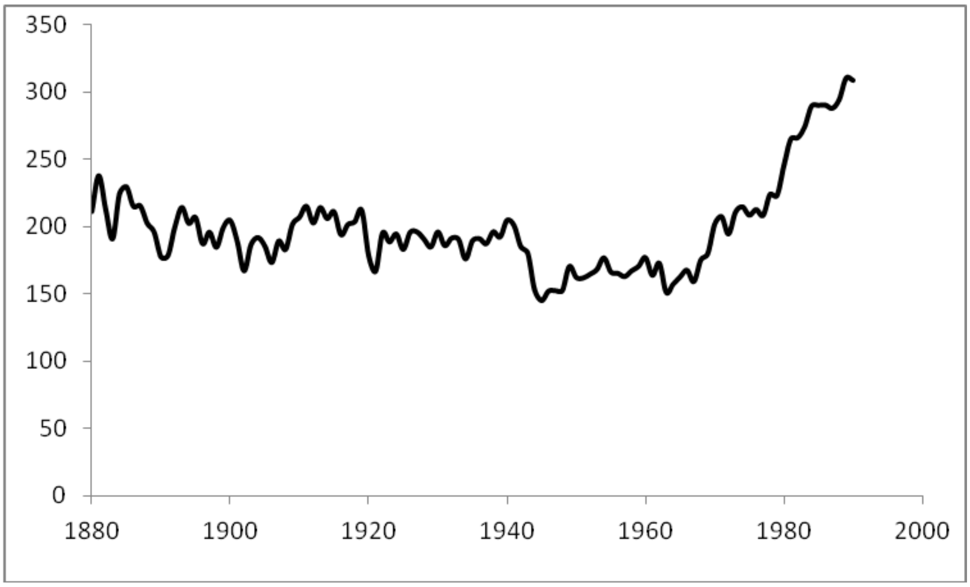
Source: Van der Eng (2000, Table 6) and this text.

Indeed, increased food consumption had a significant effect on postwar heights (Figure 5).

[9] Heights in West Java, Jakarta, and East Java increased sharply while those in central Java lagged behind, whereas all of the Outer Provinces with the exception of Sumatra maintained the same pace of increase as Java's.

Caloric intake increased from a low point of 1,626 in the period 1946-50 to 2,830 in the period 1991-95 (Van der Eng, 1994, 2000). At the same time, daily protein intake increased from 33 to 65 g, thanks largely to, on the supply side, the government's massive investments -- made possible by the increase in oil revenues during the 1970s -- in irrigation and high-yield varieties of rice, which caused an increase in per capita rice output (Figure 6), and on the demand side, a

Figure 6: Rice output (kg per capita)



Source: Van der Eng (1996b, Table A.6).

steep increase in per capita economic growth. Between 1970 and 1990 average income nearly tripled, from 1,181 to 3,276 GK dollars, with an income elasticity for rice of about 0.7 (Van der Eng, 2000). In addition, thanks to the government's pro-poor growth policy (Timmer, 2004) the poor could now afford to purchase rice, which, even if of low quality, contained more protein than did the cassava that had been a staple of their diet. Furthermore, the consumption of cassava increases the synthesis of the enzyme Rhodanese, necessary for the elimination of certain dietary toxins, and increases the body's demand for amino acids, the building blocks of proteins (Padmaja, 1996). Indeed, a survey from the 1950s shows that where cassava was the main dish, in the very poor regions of Madura and East Java, the level of protein consumption was only about two-thirds and that of vitamin B1 only about one half of the levels in regions where rice and maize were consumed instead, hampering growth and increasing vulnerability to diseases (Bailey 1962).[10]

During the early 20th century, when both average income and caloric intake were on the rise (Van der Eng, 2000), cassava had gained ground because, despite its inferiority in other respects, it was more productive than crops such as maize and rice. Since per capita production of rice remained on a plateau from 1880 to 1940 (Figure 6), the only plausible explanation for the increase in caloric consumption that leveled off around 1915 is an increase in the consumption of cassava and maize. The slight increase in protein consumption between 1900 and 1920 (Van der Eng, 2000) was primarily due to an increase in the consumption of peanuts and soybeans (ingredients of side dishes, for the most part).

How do we square this increase in average income and caloric consumption with decreases in average height? It is an established fact that in any given population the cassava-consumption level rises as the standard of living falls. Indeed, the literature on the colonial era in Indonesia features considerable discussion of the "decreasing prosperity" (or "Mindere Welvaart") in the decades around 1900 (Steinmetz, 1914; Meyer Ranneft and Huender, 1926; Rohrman 1932; Hugenholtz, 1986). Although there is some debate about the magnitude (Van der Eng, 1996), it is evident that the average income of unskilled workers declined during the first half of the century (Table 4). Combine this decline with our survey data indicating that a large percentage of the population lived in absolute poverty (Van Leeuwen and Foldvari, 2012) and that among the poor per capita caloric consumption declined (Van der Eng 2000) and it follows that the quality of nutrition among the poor must have declined as well. Thus the modest increase in caloric consumption between 1880 and 1915, thanks to a modest increase in the consumption of cassava and maize (Van der Eng, 2000), is a measure of how profound the poverty was. Indeed, it has been argued that cassava was, as a rule, served as a side dish, and only in "some poor regions of central

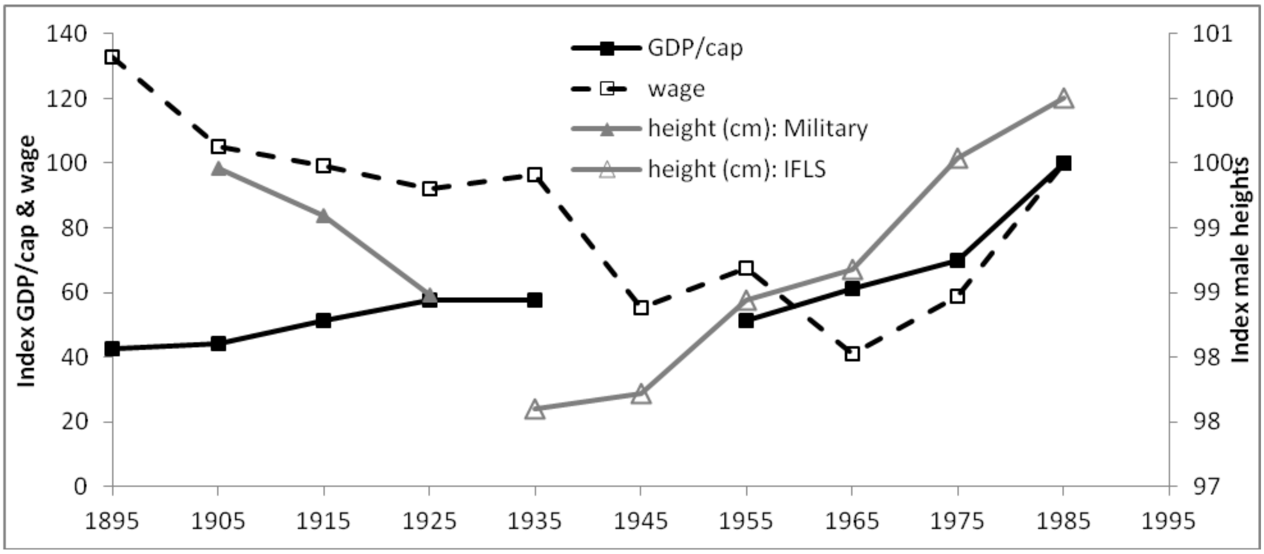
[10] Van der Eng (2000) argues that by the latter half of the twentieth century, cassava was more a snack than a staple . In fact, however, in poor areas such as Bojonegoro, cassava remained a substitute for rice. Moreover, it is probably no mere coincidence that the decrease in cassava production, which did not occur until the 1980s (as Van der Eng observes), was accompanied by an increase in per capita income.

Java, such as Bojonegoro (East Java) and Gunungkidul (close to Yogyakarta in Central Java), did cassava replace rice" (Van der Eng, 2000). This was also the case on the island of Madura, where rice was gradually replaced by other staples, including cassava, in the 1920s (Boeke, 1926).

Nutrition deteriorated during the 1920s, when rice cultivation could no longer increase; as a result, per capita caloric consumption decreased. Van der Eng (2000) argues that this decline was largely a statistical anomaly, in that it followed 1918's exceptionally high production levels (due to high international prices); that the decline was largely confined to the cassava-export market; and that therefore a decline in food production is not an adequate explanation for the fact that average height decreased during the 1920s. Like Komlos (1998) before him, he argues that when both average income and the price of food (relative to other goods) rise, consumers tend to modify their budget, substituting some new non-food expenditures for some of their previous food ones. For this theory to hold true, the income effect must be either negative or dominated by the substitution effect; and for the substitution effect to dominate, the increase in the price of food -- in this case, of rice -- must be sharper than the increase in the price of other goods. Thus if an increase in income has a negative effect on rice consumption, it follows that rice is an inferior good.

Since, as Van der Eng points out, the income elasticity of rice consumption in the 1970s was around 0.7, it is unlikely -- barring a dramatic change in tastes -- that during the prewar years rice was an inferior good. Direct evidence in support of this conclusion comes from researchers who studied coolie expenditures in Jakarta in 1937, and found that while food expenditures increased when wages increased, they decreased relative to the wage increase, again in line with an income elasticity of demand between 0 and 1 (CKS (Centraal Kantoor voor de Statistiek), 1939). The substitution effect did not take place during the 1920s, when the increase in the price of rice did not exceed (that is, did not rise relative to) the increase in the overall retail price index, much less during the 1930s, when it fell even more sharply than the prices of other products. This conclusion is corroborated by Ochse and Terra (1934), who found that in the district of Koetowinangoen, in the southern part of central Java, there was no such substitution effect. Thus the increase in average income is not an adequate explanation for the decrease in average height prior to about 1950. On the other hand, the real wages of unskilled workers provide a clue.

Figure 7: Wages, GDP/cap and heights by birth year (1985=100)



Source: GDP/cap Van der Eng (2002); Heights (this text); Wages Van Leeuwen (2007).

Whereas per capita GDP increases steadily from 1890 to 1990, these real wages decline at first only to rise subsequently, roughly in line with average height (Figure 7).

The fact that the trend in the average wages of unskilled workers proves to be a more accurate predictor of average height than is per capita GDP suggests that there was a gradual increase in income-distribution inequality; in fact, we know that during the 1920s this was the case (Booth, 1988; Leigh and van der Eng, 2009; Van Leeuwen and Foldvari, 2012). The argument that the ratio of unskilled wages to per capita GDP is a measure of such inequality has been made most effectively by Williamson (1998, ; 2000) and has been used in many other studies (Prados de la Escosura, 2008; Baten et al., 2009a). The essence of this argument is that if per capita GDP increases relative to that of the wages of unskilled workers it reflects a growing disparity between lower and upper classes in the degree to which each is profiting from economic development. By extension, the protein and calorie consumption of the lower classes may decline even as that of the upper classes soars: at this point, height becomes a measure of income inequality (Steckel, 1995).

4. Level -and distribution effects of income on height

To answer the question of why it was that around 1950 income level replaced income distribution as the motor driving average height, we decompose height development into the effect of income level, the effect of income inequality, and a residual effect incorporating factors that are not directly influenced by income.

To determine how height was affected by both the change in the income level (other, fixed, factors being denoted by X) and the change in the distribution of income (measured by a change in variance), we begin by formulating, as we did in Section 3 the relationship between income and height thus:

$$h_i = \alpha + \beta \ln y_i + \sum_{j=1}^{p} \gamma_j X_{j,i} + u_i \quad (2)$$

Since our data are limited to income and the Gini coefficients, we assume that income is lognormally distributed $\ln y \sim N(\mu, \sigma^2)$; its mean and standard deviation are denoted by *m* and *d*. We can estimate the standard deviation of the log income from the Gini coefficient under lognormality as follows:

$$\sigma = \sqrt{2}\Phi^{-1}\left(\frac{1+G}{2}\right) \quad (3)$$

We know the following about lognormal distribution:

$$m = e^{\mu + \frac{\sigma^2}{2}} \text{ and } d^2 = e^{2\mu+\sigma^2}(e^{\sigma^2} - 1) \quad (4)$$

Using these equations we arrive, after several substitutions, at the following expression for the mean of height:

$$E(h) = \alpha + \ln\left(\frac{m}{\frac{m^2+d^2}{m^2}}\right) + \sum_{j=1}^{p} \gamma_j E(X_{j,i}) \quad (5)$$

Now, with fixed *X*s, we can estimate the total effect on average height of a change in both average income and income inequality:

$$\text{total effect} = \beta\left(\ln\left(\frac{m_t}{\frac{m_t^2+d_t^2}{m_t^2}}\right) - \ln\left(\frac{m_{t-1}}{\frac{m_{t-1}^2+d_{t-1}^2}{m_{t-1}^2}}\right)\right) \quad (6)$$

$$\text{mean effect} = \beta\left(\ln\left(\frac{m_t}{\frac{m_t^2+d_{t-1}^2}{m_t^2}}\right) - \ln\left(\frac{m_{t-1}}{\frac{m_{t-1}^2+d_{t-1}^2}{m_{t-1}^2}}\right)\right) \quad (7)$$

$$\text{variance effect} = \beta\left(\ln\left(\frac{m_{t-1}}{\frac{m_{t-1}^2+d_t^2}{m_{t-1}^2}}\right) - \ln\left(\frac{m_{t-1}}{\frac{m_{t-1}^2+d_{t-1}^2}{m_{t-1}^2}}\right)\right) \quad (8)$$

This decomposition requires information on β (the coefficient of a regression between height and the log of per capita income) and the Gini coefficient. The coefficient β, which can be obtained from Table 4, is 1.24, since we use per capita GDP (abbreviated as "GDP/cap" in the table). The Gini coefficients can be obtained from Leigh and Van der Eng (2010) and Van Leeuwen and Foldvari (2012). The results of the height-development decomposition are given in Tables 5 and 6.

From the first of these two tables one can quickly deduce that in the earlier periods the income level has almost no effect on the increase in heights. For example, between 1925 and 1928 the effect of the level of income explains 0.2 cm, while the variance in income explains -0.6 cm out of a total decline in heights of -0.9 cm. The most obvious change is a decrease over time in the effect of income distribution and, on the other hand, an increase over time in the effect of income level on changes in average height: not surprising, since after 1950 income inequality declined steadily even as per capita GDP and average height rose. Nor is it surprising that in the 1950s the

Table 5

Decomposition by birth year of the income effect on height development (beta =1.41) in cm

	effect average income	effect variance of income	sum	actual height change	residual change
1925-1928	0.2	-0.6	-0.4	-0.9	-0.5
1932-1939	0.1	-0.7	-0.6	-1.6	-1.1
1939-1953	-0.2	0.7	0.5	1.7	1.2
1953-1970	0.2	0.8	1.0	1.3	0.3
1970-1980	0.6	0.2	0.9	1.0	0.1
1980-1987	0.3	0.0	0.3	0.6	0.4

Source: GDP per capita taken from Maddison (2007)

Table 6

% distribution on height development by birth year with coefficient=1.41

	Income effect			**residual**	**total change**
	effect average income	effect variance of income	*sum*		
1925-1928	-21%	66%	*45%*	*55%*	*100%*
1932-1939	-8%	42%	*34%*	*66%*	*100%*
1939-1953	-12%	40%	*28%*	*72%*	*100%*
1953-1970	16%	61%	*77%*	*23%*	*100%*
1970-1980	63%	23%	*86%*	*14%*	*100%*
1980-1987	45%	-5%	*40%*	*60%*	*100%*

effect of mean income on height began to surpass that of variance, since as a rule the impact of variance declines as larger share of the population rises above the subsistence level. The fact that beginning in the 1950s the food portion of the household budget steadily decreased indicates that the standard of living was improving; the government's pro-poor growth policy contributed to this improvement, as well.

This pattern has not been confined to Indonesia. During the First Industrial Revolution, there was a height decline not only in Great Britain and the US (Margo and Steckel, 1983; Komlos, 1998), but also in Italy (Peracchi, 2008), the Netherlands (Haines, 2004). In all of these cases the decrease in average height was accompanied by an increase in per capita GDP (Maddison, 2007).

On the other hand, real wages remained flat or even declined (Allen, 2001). When this is the case, height development is driven primarily by income inequality; in other words, since “the gain in height at the individual level increases at a decreasing rate as a function of income, one would expect average height at the aggregate level to rise, for a given per capita income, with the degree of equality of the income distribution." (Steckel 1999). Indeed, when the wages of unskilled workers were flat or declining and per capita GDP was rising, inequality could only have increased (Williamson, 1998).

The latter half of the twentieth century was marked by a different phenomenon: a simultaneous increase in per capita GDP, real wages, and heights, the correlation between the latter two being particularly close (Steckel, 1995) -- that can be explained by the fact when income increases but income elasticity is less than unit, the food portion of the household budget shrinks (provided relative prices were broadly stable, which was the case during the latter half of the twentieth century). In other words, the level of income becomes more important than its dispersion. It may have been thanks to this phenomenon that 1950s Indonesia "managed to escape the decline in the biological standard of living that stunted Western Europe and North America during the late eighteenth and early nineteenth centuries" (Van der Eng, 2006).

5. Conclusion

This study of the relationship between income and height in 20th-century Indonesia is based on a military records from the years 1945-47 in which the heights of recruits were recorded, and two Indonesia Family Life Surveys, those of 1992 and 2007.

We find that until about 1950 there is little correlation in Indonesia between per capita GDP and height (the case in other countries, mostly developed ones, as well), because, while average protein and calorie consumption increased, so did income inequality, as measured by changes in the wages of unskilled workers, a reliable predictor of changes in average height (Williamson, 1998).

At this point, three changes that favor an increase in average height occurred: average income increased (accounting for a decline in the food portion of the household budget); the government instituted pro-poor growth policies, reducing income inequality; and rice consumption, and therefore calorie and protein consumption, increased. This caused stature to increase again in line with GDP per capita.

Quantifying the reversal, we find that income inequality drove height development prior to 1950 for ca. 50% while after 1950 inequality drove the development of average heights for less than 20%. The reversal in mid-century of the height trend occurred throughout Indonesia but was especially dramatic on Java, where heights and income (excluding that derived from the oil industry) soon surpassed those of the Outer Provinces. This reversal follows a pattern found among several Western countries a century or so ago, when they were, socio-economically, at a point in their history uncannily akin to that of Indonesia today. This shows that anthropometry as a measure of biological welfare provides researchers with the means not only to measure biological change (for better or for worse), individual or collective, over the course of one or of many lifetimes, but also to determine the socio-economic factors (like inequality) responsible for these changes: information that can contribute significantly to public-policy reform in countries with scarce data.

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Appendix: Correcting for truncation with skewed normal distribution

The pdf of the SN is where is the density function of the standard

normal distribution, and . Since , this probability distribution has three parameters: $\mu_{y,}$ σ_y and the skewness parameter α. If $\alpha=0$, we have the standard normal distribution and then μ_y and σ_y equal the mean and the standard deviation of the variable, otherwise the sign of the parameter is indicative of the skew: positive (right) or negative (left). As we have pointed out, because a large share of the population was at the absolute poverty level before the war, we expect there to be a positive skewness (the mode is lower than the median and mean), indicating an increasingly large base of shorter people. The parameters are estimated with an ML procedure.

We used the above distribution with our truncated sample (recruitment data with minimum height requirement). In this case we followed the standard procedure: that is, the density of a truncated skew-normal distribution is:

,

where *a* denotes the truncation point.

Table A.1

	μ_y	σ_y	α	mean (cm)	std dev (cm)
	Military data				
pre-1920	156.6	8.06	2.77	162.5	5.47
1920-1928	156.3	7.24	1.95	161.4	5.12
	IFLS data				
1930-1940	154.9	7.25	0.93	158.9	6.09
1940-1950	162.9	6.55	-0.64	160.1	5.91
1950-1960	164.3	6.55	-0.74	161.2	5.76
1960-1970	159.1	6.17	0.60[a]	161.6	5.62
1970-1980	166.5	6.87	-0.81	163.0	5.94
1980-1990	167.0	6.75	-0.74	163.8	5.95

Note: [a] this is the only case when in which the skewness parameter was not significant at 1%.
Note: μ_y , σ_y and α are parameters of the skewed normal probability distribution. They are not the mean or the standard deviation of the variable except if α=0, that is the distribution is symmetrical. If this is not the case, the mean and the s.d. must be calculated from the three parameters and that is what is reported in the last two columns.

The importance of correcting for truncation when estimating the population mean and standard deviation is well known. Using the skewed normal distribution adds (besides a more exact estimation of mean population height) the possibility of observing how the asymmetry of height changed over the course of the century. We can see in Table A.1 that initially there was positive skewness (that is, the mode is lower than the median and mean), indicating that a large percentage of the population was living at the subsistence level: a situation that gradually changed during the 1960s. Throughout the second half of the century, however, height was evidently skewed to the left: scarcely surprising since, as we have noted, there was a sharp decline in the percentage of the population living at the absolute poverty level. Indeed, most people were well fed and reducing the food portion of their household budget in favor of purchases of other sorts of goods.