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The Height of Women in Sub-Saharan Africa: the Role of Health, Nutrition, and Income in Childhood

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Abstract

Background:

Adult height in individuals has been linked to health and nutrition in childhood, and to health outcomes in later life. Economists have used average adult height as an indicator of the biological standard of living and as a measure of health human capital. However, it is unclear to what extent childhood health and nutrition are reflected in adult height at the population level.

Aim:

We examine the proximate determinants of population adult height for countries in Sub-Saharan Africa.

Subjects and Methods:

We create a database of adult female height for twenty-four countries in Sub-Saharan Africa for birth cohorts born between 1945 and 1985. We study the effect of infant mortality rate, GDP per capita, and average protein and calorie consumption on cohort adult height.

Results:

Most of the variation in height across countries in Sub-Saharan Africa is due to fixed effects, however, we find that variations in cohort height over time are sensitive to changes in infant mortality rate, GDP per capita, and protein intake, both at birth and in adolescence.

Conclusions:

Changes in cohort adult height over time in Sub-Saharan Africa are related to changes childhood health and nutrition, though variation across countries appears to be determined mainly by unexplained fixed factors.

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1. Introduction

There is extensive evidence at the individual level that childhood health and nutrition affect physical growth and height as an adult (Steckel 1995, Blackwell et al. 2001). In terms of nutrition, protein intake is often emphasized (Martorell and Habicht 1986) though calorie consumption can also be a limiting factor (Martorell 1976, Hegsted, 1971). Infections in early life, particularly those that lead to diarrhea, can also affect physical development (Brush et al.1997, Liu et al. 1998). Poor nutrition and disease can interact, with poor nutrition increasing the likelihood of infection and infection impairing nutrient absorption (Stephensen 1999, Scrimshaw 2003).

The sensitivity of adult height to childhood living conditions has led to the use of height as a measure of the "biological standard of living" in economic history when studying populations for which more conventional measures of living standards are absent (Komlos 1993, Steckel 1995, Steckel et al. 2002, Steckel and Prince 2001). The modern era appears to have witnessed a "techno physiological revolution" due to increased net nutrition (based on food consumption minus the demands placed on the body by work and disease) increasing physical robustness and labor productivity (Fogel 1993, Fogel and Costa 1997, Fogel 2004). There is also evidence that in developing countries, improvements in childhood health and nutrition that lead to greater adult height generate gains in worker productivity (Schultz 2002, Schultz 2005).

There is an established connection between childhood health, nutrition, and adult height at the individual level (Silventoinen 2003). Other studies have investigated the link between population height and population health and nutrition (Jamison et al. 2003, Komlos and Baur 2004, Crimmins and Finch 2006, Moradi 2002, 2006, Deaton 2006). In cross section studies of counties in China, and across countries, greater average protein intake is associated with greater average adult height (Jamison et al. 2003). Falling rates of mortality in childhood have been associated with rising average adult cohort heights in Sweden, France and England since the 19th century (Crimmins and Finch 2006). Variations in average height in Sub-Saharan Africa are linked to economic growth, civil war, and openness to foreign trade (Moradi 2006). Deaton (2006) examines the question of why Africans are so tall and finds a large role for fixed effects in addition to income levels and the child mortality rate.

We investigate the relationship between nutrition, income, health, and cohort height in low-income Sub-Saharan Africa countries using data from the second half of the twentieth century. Preliminary investigations showed that the relationship appears to differ significantly between low-income, middle–income, and high-income countries, and pooling these could produce misleading results; we therefore focus only on low-income countries. In addition, low-income countries today have the most similar environments to those examined in historical studies of the biological standard of living and may provide insights for such studies.

Focusing on low-income countries, however, produces a sample that is almost entirely made up of countries from Sub-Saharan Africa, and it may be that Sub-Saharan Africa differs from the rest of the world. Sub-Saharan Africa has experienced a lower decline in infant mortality than the rest of the world, and slightly increased underweight prevalence, on average, while all other regions saw improvements (Pelletier and Frongillo 2003, Onis et al. 2004). Klasen (2000) shows that for children, the relationship between anthropometric outcomes and environmental factors appears to be different in Africa and Asia. Rather than pooling all low-income countries, we exclude the small number of non Sub-Saharan Africa low-income countries for which data is available. Gabon is the only Sub-Saharan Africa country for which we have data that is classified as middle-income and thus is excluded from the sample.

We can distinguish between proximate determinants of adult height, including childhood health and nutrition, and more distant underlying socioeconomic causes, such as cultural values, and public health measures, that operate via influencing the proximate determinants (Steckel 1995). We focus exclusively on the proximate determinates of height and explain adult height by the infant mortality rate, GDP per capita, and the intake of protein and calories during the cohort's childhood. There is a question as to whether income per capita should be considered a proximate determinate itself or as a distal factor that affects height through its impact on nutrition and health. We find a significant impact of income per capita during childhood on adult height, even after controlling for nutrition and health suggesting it acts as a proximate determinant (or as a proxy for an unobserved proximate determinate such as housing, clothing, or healthcare).

Our measures of the proximate determinants are not perfect. Protein and calories are important dimensions of nutrition but do not capture micronutrients that may be important for childhood development (Branca and Ferrari, 2002). Adult height depends on childhood morbidity: we proxy this by childhood mortality which may be problematical if the relationship between morbidity and mortality varies across populations and over time. Higher income per capita provides greater resources for child development (Pritchett and Summers (1996)) and may act as a proxy for some unobserved proximate determinate; but we would prefer to measure these proximate factors directly.

We include country fixed effects to allow for the possibility of other factors that influence height that differ across countries, but are fixed over time. We find these fixed effects to be highly significant. It is tempting to think of these country fixed effects as reflecting genetic variation. At the individual level, there is evidence from developed countries that up to 80% of variation in the heights of individuals can be ascribed to genetic factors (Stunkard et al. 1986, Silventoinen 2003). In comparisons of populations, however, there is a debate as to whether genetic variation is important. The "conventional wisdom" is that in well-nourished populations, the effects of genetic factors on average adult height are small. The differences in height among the well-off social classes across populations tend to be small compared to differences in height across individuals within a population. This is based originally on work by Martorell and Habicht (1986), who find that average height of boys aged 7.5 years in well-nourished elite populations ranged only about 6cm across population groups, while the within-population between-social-class range is as much as 12cm in others (Eveleth and Tanner 1976, 1990).

However, this view that genetic potential is essentially the same across different populations has been called into question. Variations in height and body shape between populations in different geographical areas may be caused by natural selection based on millennia of differential climatic influences and technological sophistication (Ruff, 2002)[i], [ii] though this effect may be weaken in modern populations by large scale migrations. Klasen

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[i] Ruff states that "the nutritional and overall health levels may account for an increasing proportion of variation" in the recent secular trends, and that "in assessing anthropometric variation in living populations, it is important to consider the influence of both kinds of factors (log-term genetic factors and short-term nutrition and health environments) in order to distinguish one from the other".

[ii] Effects of migration were not considered in this paper. Inspired by economic opportunities or driven by wars and conflict, people have migrated enormously over the past couple of centuries, quite possibly enough to dampen or even eviscerate the genetic factors identified by Ruff (assuming systematic genetic differences that were large arose from this mechanism).

(2000) and Klasen and Moradi (2000) find substantial differences in anthropometric outcomes among well-nourished children in different countries. The World Health Organization generates child growth charts for well-nourished children that average over populations from poor and rich countries which may be more representative of different populations than the common practice of using data from the United States to form a reference group (de Onis et al. 2007).

It seems difficult to argue that genetic variations within Africa are large enough to generate the range of fixed effects we observe. However it is an open question whether the explanation of our results is non-genetic country specific factors, or if there is a need to rethink the argument that average adult height for individuals that were well nourished and had low morbidity in childhood is the same for all populations. Our results do suggest, however, that factors other than health and nutrition can affect population height and that caution should be taken when using differences in heights across very different populations to make inferences about their relative biological standard of living.

Adult height reflects the health and nutrition environment in which the person grew up, and it is usually completely determined by the time the person reaches the age of 20. Therefore, in a rapidly changing health environment, adult height may not correspond to current environmental factors such as mortality and morbidity rates. Infant mortality can be considered a generic measure of health conditions (say, exposure to pathogens) across all ages (Crimmins and Finch 2006). However, we wish to investigate the effect of conditions at different points through childhood on physical development and adult height. The effect of nutrition on height may start as early as fetal life (Kusin et al. 1992, Barker et al. 1993) and nutrition and health in the first three years of life are highly significant for physical development (Ulijaszek 1990, Baten

2000). On the other hand, there are findings that health and nutrition in puberty also play a significant role in determining final height, with the possibility of catch-up growth if stunting takes place in early life (Steckel 1987). We examine the effect of health, income and nutrition at birth (which may also capture neo-natal conditions), and ages 5, 10, and 15.

We find that infant mortality, protein intake and GDP per capita at birth, and age 15, play a role in determining the adult height of women. Even after controlling for these factors, we find a significant downward time trend in heights. This may be evidence of a decline in the biological standard of living, but could also reflect a changing relationship between health, as measured by infant mortality rates, and height. Health advances may reduce mortality with little effect on morbidity and the stature of the survivors (Huffman and Steel 1995). Height may be determined by childhood morbidity and while the infant mortality rate is a proxy for the morbidity burden, the relationship between the two can change over time.

2. Data

All our data are taken from Demographic and Health Surveys, 2005[iii]. All available DHS surveys for low-income Sub-Saharan Africa countries (as defined by the World Bank, 2005[iv]) that include women's height as a variable were employed. Standing height, without shoes, is measured by the interviewer using a headboard. The typical DHS dataset measures the height of women from age 15 to 49. These are nationally representative samples; we use the sampling

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[iii] Demographic and Health Surveys. 2005. Available on line http://www.measuredhs.com/.

[iv] World Bank. 2005. http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20420458~menuPK:64133156~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html 1, October, 2006.

weights provided to construct average height for each cohort. We use heights of women only from age 20 and above on the grounds that, in most cases, physical development has ceased by age 20, and make no adjustments for shrinkage in height with age, which is likely to be very small over this range. The number of observations in a typical DHS data set is around 4000, though there is variation in sample size by age within a survey as well as across countries and time.

A complication is that while in later DHS surveys the height of all women 15 to 49 was measured, in earlier surveys only the height of mothers with children under 5 were taken. This creates a sample selection problem since mothers are not randomly selected; for example, if height is positively linked to high socioeconomic status, and high socioeconomic status is linked to low fertility, mothers will tend to be shorter than average. However, the almost universal high fertility found in low-income countries means that the bias should be small (Moradi 2006). In our check of data consistency, we examine the height of each cohort as measured in different DHS surveys and find them remarkably similar despite some being for mothers while others include all women.

We examine the distribution of adult female heights for each of our surveys. Table I shows some descriptive statistics for the distribution of cohort heights for cohorts born in 1960, 1965, 1970, 1975, and 1980 from the Cameroon 2004 DHS survey. The standard deviation of individuals' heights is around 6 centimeters. There is some evidence of a positive (right) skew in most cohorts. Cohorts from 1960, 1970, and 1980 have kurtosis less than 3 (so that the peak of the distribution is lower and fatter, with thinner tails, than the normal), while 1965 cohort has a larger than 3 kurtosis with higher and narrower peak. Tests of the hypothesis that the distribution is normal fail to be rejected for all cohorts. Figure 1 shows the estimated distribution of heights of the cohort born in 1980 in Cameroon, generated using a kernel estimator, showing a right skew, lower peak, and thinner tail relative to the normal distribution. The rejection of normality is in fact common in many of our datasets. The deviation from normality can be taken as evidence of a selection effect, which could potentially be corrected by statistical methods. However, it is possible that differential health and nutrition across individuals creates a non-normal distribution and that a "correction" to produce normality would bias the results (Jacobs, Katzur and Tassenaar 2004).

We construct average height for each cohort by year of birth from each survey. For each country with multiple DHS surveys, adult female cohort heights by birth years were graphed to check for consistency when the same cohort is included in different surveys. Examples for the DHS surveys of Cameroon in 1998 and 2004 as well as their average are shown in Figure 2. In most cases the results for different surveys were very similar. Note that the large variations in average heights between the early birth cohorts are based on small sample sizes.

In order to view the trend in adult female height in Sub-Saharan Africa, we run an ordinary least squares regression separately for each country including only a constant and a time trend. The results of these regressions are reported in Table II. The trends in height are mixed. In Kenya and Senegal, we find evidence of an upward trend in cohort height; however, Chad and Ethiopia appear to have a downward trend in height. Other countries have no significant time trends. In addition to examining time trends, we also test for autocorrelation. We find no evidence of pervasive autocorrelation in cohort heights.

Our average adult female height estimates are based on samples and are subject to sampling variation. For an average based on a sample of size n the standard deviation in estimated average height is $\sigma/\sqrt{n}$, where σ is the standard deviation of heights in the population. With a standard deviation in heights of around 6 centimeters this gives us a standard deviation in estimated cohort height of around 0.41 centimeters for cohorts with an average sample size (212 individuals), but a standard deviation as high as 4.24 centimeters for cohorts with small sample sizes and as low as 0.22 centimeters for cohorts with averages based on large samples. This sampling variation produces noise in the data and implies a low signal to noise ratio in short run movements in average height; most of the variation in average height from year to year shown in Figure 2 is due to sampling error.

We compare adult female height with a number of indicators for health, nutrition, and income. For health, we use infant mortality rate from the World Bank's World Development Indicators (2005), which gives data back to 1960; we linearly interpolated over gaps of one to two years to derive an annual time series. We use this as our measure of population health, though infant mortality depends on nutrition as well as the disease environment, and thus is not a pure health measure (Baten 2000). We use GDP per capita (purchasing power parity adjusted) from the Penn World Tables 6.1 (Heston, Summers and Aten, 2002). For nutrition, we use daily average consumption of calories and protein from the World Food Organization FAOSTAT database[v], with annual data going back to 1961.

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[v] Food and Agricultural Organization. 2006. FAOSTAT data, Food Balance Sheets. http://faostat.fao.org/?alias=faostatclassic 12, October, 2006.

3. Proximate Determinants of Height

We can think of the proximate determinates of height as being nutrition, and morbidity due to the disease environment. In addition, we add income per capita as a general measure of the availability of resources, such as housing, clothing, and medical care that may mitigate the health effects of the disease environment. (Deaton (2006) does not include nutrition as a determinate of height but uses income as a proxy; the effect of income in our framework is its additional contribution to height over and above any influence on nutrition). We represent this relationship explaining the adult height of the cohort born in year t in country i in equation (1)

$$h_{it} = f_i + \alpha n_{it} - \beta d_{it} + \gamma y_{it} \qquad (1)$$

where *h* is adult height, n is childhood nutrition, d is the childhood disease environment, and *y* is income per capita in childhood. We include a fixed effect *f* to allow for country specific unobserved variables that may affect adult height. Estimating this model is complicated by the fact that we do not have a measure of the disease environment in childhood. We could simply proxy this by the infant mortality rate. However, there is strong evidence that the infant mortality rate falls exogenously over time. This can be thought of as technological progress in preventing mortality, giving rise to a changing relationship between the disease environment and the mortality rate over time. Equation (2) assumes that infant mortality, *m*, is increasing in the disease burden but also depends on time specific dummies that reflect technological progress.

$$m_{it} = \delta d_{it} + \sigma_t \qquad (2)$$

Combining equations (1) and (2) we have

$$h_{it} = f_i + \alpha n_{it} + \gamma y_{it} - \frac{\beta}{\delta} m_{it} + \frac{\beta}{\delta} \sigma_t \qquad (3)$$

In equation (3), we have that height is increasing in childhood income level and nutrition and falling in the infant mortality rate in childhood. The time dummies capture the changing relationship between the infant mortality rate and adult height over time. Technological progress that reduces the mortality effects of disease, without reducing the morbidity effect, will produce dummies that decline over time.

In addition to the issue of which variables to include as proximate determinants of height, we have to address the issue of timing of the effects. We begin our empirical investigation by regressing average cohort height for adult female on the infant mortality rate, GDP per capita, average protein intake, and average calorie intake at birth and ages 5, 10 and 15. We also included time dummies for each year and country fixed effects. A likelihood ratio test rejected a linear trend against the more complex model with time dummies. The country fixed-effects were jointly highly significant. In all our reported regression we include fixed effects and time dummies. In addition, we found strong evidence of heteroskedasticity, with the variance of the residual being inversely proportional to the sample size. We therefore use weighted least squares, with the weights being the sample size on which the average height is based (which is inversely proportional to the variance of the estimated average height). This gives more weight to observations for which the average height is based on large samples and which have a higher ratio of signal to noise. As can be seen in figure 2, averaging over two DHS surveys for birth cohorts in the middle period reduces the noise in the average height, as compared to observations at the beginning and end of the period when data from only one DHS is available.

Table III reports our results. Column 1 reports the effect of income per capita, infant mortality rate, protein intake, and calorie intake at birth and ages 5, 10 and 15. We begin by testing the hypothesis that each factor has no effect at all ages. Table IV reports likelihood ratio tests of the joint hypothesis for each indicator, i.e. income per capita, infant mortality rate, protein, and calories. The test of coefficients on GDP per capita and infant mortality rate (both for all ages) is each rejected and therefore remain in the model. The test for protein intake is also rejected and remains in the model. The one on calorie intake, however, fails to be rejected, and we therefore drop calories from the regression.

In the regression reported in Column 2 of Table III, we find that the infant mortality rates are not significant while GDP per capita at ages 5 and 15 as well as protein at birth and at age 15 are positively related to adult height. A joint test that the coefficients on all the age 5 and 10 variables were zero fails to be rejected. We therefore drop these variables from the regression.

Column 3 of Table III reports a regression containing the infant mortality rate, protein intake, and GDP per capita indicators, measured only at birth and age 15. We now find that high infant mortality at birth appears to reduce adult stature while good nutrition at birth and age 15 as well as GDP per capita at age 15 increase the final height. Infant mortality rate at age 15 and GDP per capita at birth do not appear to be significant and are dropped in the regression reported in Column 4. Increase in infant mortality rate of 100 (per 1,000) is associated with 2.5cm decrease in adult average height, while 1% increase in GDP per capita leads to nearly 1cm increase in height. 10g/per day increase in protein intake at birth is associated with 0.3cm increase in height while the same increase of protein intake during adolescence leads to 0.1 cm increase in height. From the size of the coefficients, nutrition at birth appears more important for adult height than nutrition at age 15, the latter coefficient being about a third of the former.

We find a significant negative time dummies effect (Figure 3). This negative time dummies effect may reflect omitted variables that negatively impact height and is indicative of a negative trend in the biological standard of living in Sub-Saharan Africa. It may also reflect a changing relationship between health as measured by mortality rates and stature. This suggests the need for a more detailed measure of health than mortality rates, particularly measures that reflect the disease environment and morbidity, in understanding the evolution of heights. However, the interpretation of the time effect remains an open question.

As in Deaton (2006), there are large and highly statistically significant country fixed-effects in the data; the fixed effects account for around 90% of the explanatory power of our model. Table V gives the estimated fixed effect for each country in the regression reported in Column 4 of Table III. They are very large in magnitude, with a range of over 11 centimeters between Mali, where people are, on average, tall given its health and nutrition indicators and Madagascar, where people are short given the environment. At this point, there is little we can infer from the fixed effects and what they may mean. In principle, they represent country specific, time invariant, omitted variables that affect height. They may reflect genetic differences between the populations, but genetic effects alone are unlikely to be the sole cause of these significant fixed effects. There is also the omitted variable problem; the country fixed effects could capture forces such as inequality in nutrition, which are omitted from the model. It is also possible that systematic measurement error in one of our variables creates country-specific shifts in the relationship that are corrected by the fixed effects. For example, non-reporting of the informal sector of the economy may lead to a systematic under estimation of GDP per capita in some countries.

Whatever the causes, the fixed effects suggest that we need to be cautious when drawing inferences about nutrition and health from comparisons of average height between populations from different countries in Sub-Saharan Africa. In addition, we find that excluding the fixed effects results in parameter estimates for the effects of infant mortality and nutrition that are very different, and sometimes the opposite sign, to those that we report, suggesting that including the fixed effects is important for understanding the relationship.

4. Conclusion

Cohort heights for adult female vary systematically with health and nutrition in Sub-Saharan Africa. Good nutrition and health conditions in infancy and in adolescence are positively associated with average adult female height. Our findings at the population levels are in agreement with studies at the individual level in finding nutrition and disease around the time of birth, and in adolescence, as being crucial to physical development. However, our understanding of the relationship at the population level is complicated by the presence of country fixed effects and time dummies. The country fixed effects indicate that care must be taken in using differences in height between countries as an indicator of differences in health and nutrition.. The trend of the time dummies suggests that the relationship also changes over time. This may be due to mortality rates and average height reflecting different dimensions of population health that advance at different rates during the epidemiologic transition. Adult height may be better thought as a different measure of population health than infant mortality rate, rather than simply a proxy for mortality when data is missing. We would argue that the unexplained fixed-effects and time dummies generate a need to launch a broad-ranging search for explanations in future research.

A weakness in our approach is that we do not take account of differences in the distribution of health and nutrition within countries and the impact of inequality on average heights. We lack the data on the distribution of health and nutrition required for such a study though it is likely that distribution matters for average outcomes.

Figure 1

Distribution of Female Adult Heights

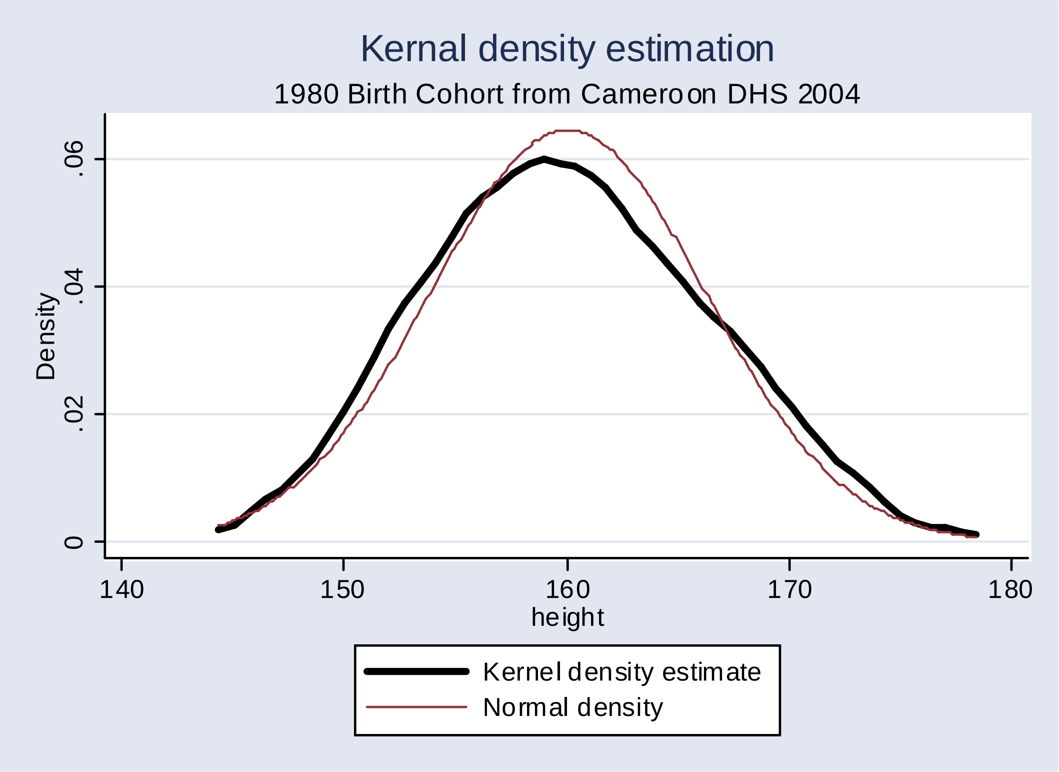

Figure 2

Cameroon: Average Cohort Heights of Females by Birth Year

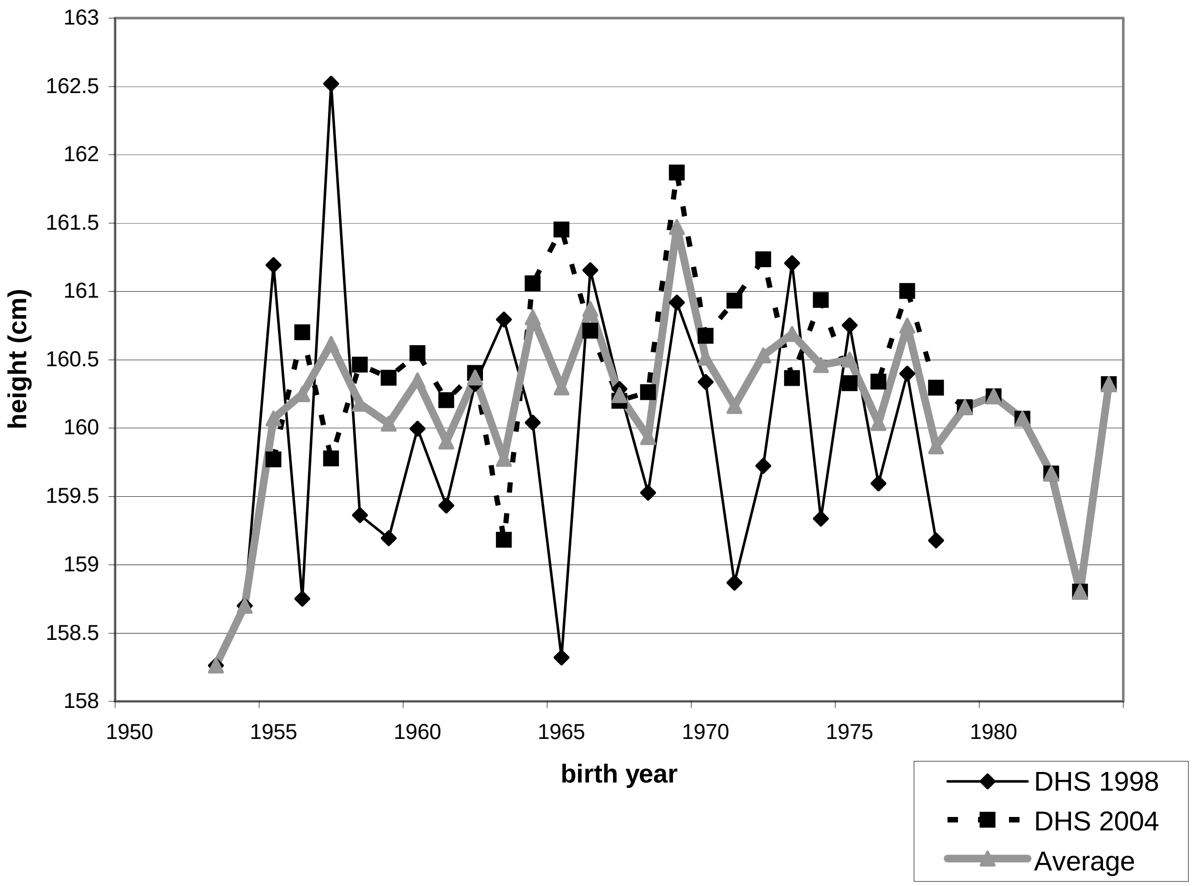

Figure 3

Coefficients for Time Dummies in the Final Model

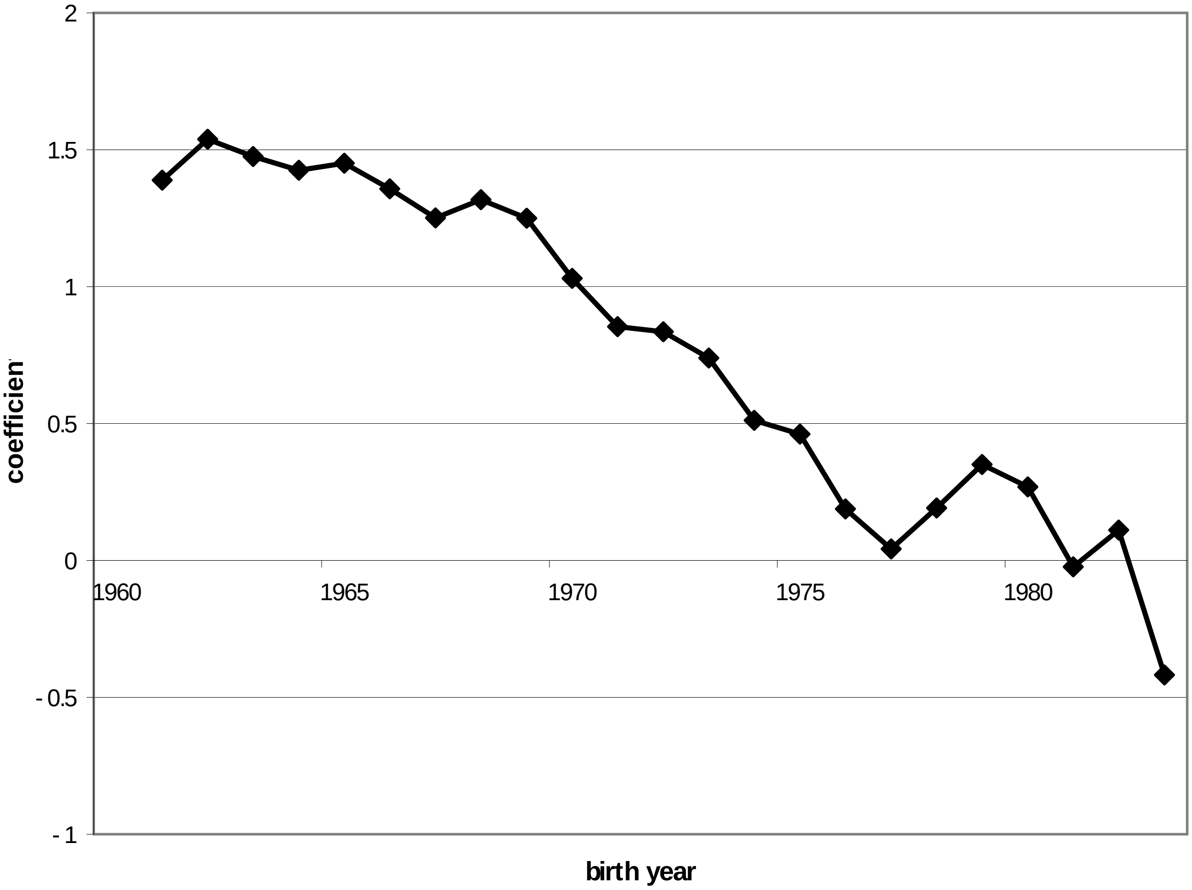

Table I

Descriptive Statistics and Distributional Tests
Female Adult Height

Cameroon DHS 2004

Birth Cohort	**1960**	**1965**	**1970**	**1975**	**1980**
Observations	80	82	127	133	203
Mean height	160.53	161.03	160.37	160.18	160.04
Standard Deviation	6.20	6.23	6.57	6.30	6.20
Skewness	0.30	0.04	-0.11	0.01	0.18
Kurtosis	2.71	3.86	2.76	3.05	2.56
Normality test: Shapiro-Wilk p-value	0.32	0.12	0.70	0.96	0.34

Table II
Time Trends in Adult Female Cohort Height

Country	Time	Constant	Cohorts	Data Source
Benin	-0.001 (0.014)	158.69*** (0.281)	1952-1981	DHS 1996 DHS 2001
Burkina Faso	0.007 (0.007)	161.44*** (0.169)	1958-1985	DHS 1998 DHS 2003
Cameroon	0.010 (0.012)	159.91*** (0.306)	1953-1984	DHS 1998 DHS 2004
Central Africa Republic	0.069 (0.042)	157.33*** (0.833)	1954-1974	DHS 1994
Chad	-0.034** (0.016)	163.35*** (0.372)	1949-1984	DHS 1997 DHS 2004
Comoros	-0.054 (0.042)	155.91*** (0.871)	1959-1972	DHS 1996
Cote d'Ivoire	0.024 (0.023)	158.55*** (0.447)	1953-1974	DHS1994
Ethiopia	-0.054*** (0.015)	156.97*** (0.285)	1945-1977	DHS 2000
Ghana	0.018 (0.015)	158.26*** (0.355)	1949-1984	DHS1993 DHS 1998 DHS 2003
Guinea	-0.021 (0.023)	159.17*** (0.489)	1949-1979	DHS 1999
Kenya	0.050*** (0.010)	158.39*** (0.231)	1945-1983	DHS1993 DHS 2003
Madagascar	-0.024 (0.017)	153.63*** (0.355)	1951-1977	DHS1997
Malawi	-0.005 (0.009)	156.18*** (0.191)	1950-1980	DHS 2000
Mali	0.015 (0.015)	161.18*** (0.287)	1949-1975	DHS 1995
Mozambique	-0.011 (0.020)	155.73*** (0.468)	1978-1983	DHS 1992 DHS 2003
Niger	-0.015 (0.001)	160.60*** (0.187)	1946-1978	DHS 1992 DHS 1998
Nigeria	-0.010 (0.017)	158.75*** (0.409)	1952-1983	DHS 1999 DHS 2003
Rwanda	-0.023* (0.012)	158.37*** (0.268)	1950-1980	DHS 2000
Senegal	0.074*** (0.025)	161.11*** (0.389)	1945-1972	DHS 1992

Tanzania	0.005 (0.021)	156.30*** (0.398)	1947-1976	DHS 1996
Togo	-0.008 (0.025)	158.97*** (0.505)	1948-1978	DHS 1998
Uganda	-0.008 (0.018)	158.51*** (0.388)	1946-1981	DHS 1995 DHS 2000
Zambia	0.013 (0.013)	157.90*** (0.283)	1948-1981	DHS 1996 DHS 2001
Zimbabwe	-0.009 (0.023)	159.55*** (0.417)	1949-1974	DHS 1994

Coefficients, standard errors in parentheses, significance level indicated as *(10%), **(5%), ***(1%)
Time=Year-1950.

Table III The Proximate Determinants of Adult Female Cohort Height

Average cohort height	**1**	**2**	**3**	**4**
Constant	145.97*** (3.02)	146.75*** (2.95)	149.84*** (2.59)	152.66*** (1.73)
Infant Mortality Rate at birth	-1.48 (1.21)	-1.56 (1.21)	-2.66*** (0.47)	-2.50*** (0.45)
Infant Mortality Rate at age 5	-2.93 (1.96)	-2.70 (1.95)		
Infant Mortality Rate at age 10	3.13* (1.68)	2.64 (1.63)		
Infant Mortality Rate at age 15	0.38 (0.96)	0.39 (0.92)	0.80 (0.56)	
GDP per capita at birth	-0.12 (0.26)	-0.13 (0.25)	0.15 (0.21)	
GDP per capita at age 5	0.59** (0.25)	0.49** (0.24)		
GDP per capita at age 10	0.37 (0.27)	0.27 (0.26)		
GDP per capita at age 15	0.89*** (0.29)	0.94*** (0.29)	1.11*** (0.26)	0.98*** (0.24)
Protein at birth	4.29** (1.68)	3.47*** (0.78)	3.05*** (0.74)	3.07*** (0.73)
Protein at age 5	-0.36 (1.56)	-0.86 (0.75)		
Protein at age 10	3.71** (1.55)	1.37 (0.693)		
Protein at age 15	0.40 (1.35)	1.10** (0.68)	1.41** (0.60)	1.17** (0.58)
Calories at birth	-0.04 (0.06)			
Calories at age 5	-0.01 (0.05)			
Calories at age 10	-0.07 (0.05)			
Calories at age 15	0.02 (0.04)			
N	438	438	438	438
R-squared	0.958	0.958	0.956	0.956

Data from 24 countries. Coefficients estimates with standard errors in parentheses, significance level indicated as *(10%), **(5%), ***(1%). We include a fixed effect for each country and time dummies. Each observation is weighted by the number of heights used to calculate the cohort average height. The infant mortality rate is deaths (per 10 births) before age one, while protein is 100g/day/person, and calories 100calories/day/person. GDP per capita is in natural logarithms.

Table IV

Test of Coefficients at ages 0, 5, 10, 15

	Infant mortality	**GDP per capita**	**Protein**	**Calories**
F test	F(4,375) = 8.83	F(4,375) = 6.77	F(4, 375) = 2.71	F(4,375) = 0.80
p-value	0.001<	0.001<	0.030	0.525
H_0	Reject	Reject	Reject	Fail to Reject

Table V

Estimated Country Fixed effects

Country	Fixed Effects
Madagascar	-7.03***
Comoros	-4.19***
Zimbabwe	-2.58***
Ethiopia	-2.47***
Mozambique	-2.22***
Tanzania	-2.19***
Malawi	-1.98***
Zambia	-1.90***
Rwanda	-1.56***
Uganda	-1.05***
Kenya	-1.03***
Ghana	-0.76***
Nigeria	-0.73***
Togo	-0.67***
Cote d'Ivoire	-0.43
Benin	0 (reference)
Cameroon	0.02
Guinea	0.26
Central African Republic	0.35
Niger	2.35***
Senegal	2.94***
Burkina Faso	3.25***
Chad	3.62***
Mali	4.54***

From Column 4 regression in Table III. Coefficients, significance level indicated as *(10%), **(5%), ***(1%)

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