Nutritional Status and Economic Development in Sub-Saharan Africa, 1950-1980

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Abstract
How did nutritional status develop in sub-Saharan Africa, and what role did economic development play in nutrition and health? Aggregating data from more than 200,000 women in 28 sub-Saharan African countries, I use mean population height as an indicator of net nutritional status and find that, overall, the nutritional status of 1960 birth cohorts was in a good state. This situation, however, was not sustained. In almost all African countries, mean heights were stagnating or decreasing in 1970, with later cohorts indicating a severe nutritional crisis. In a regression analysis, I model the entire span of bodily growth, from birth to maturity, and find that economic growth had a significant and very robust influence on final adult height at two distinct periods: (1) in the first years of life and (2) at puberty. These results are robust when considering economic development as endogenous to nutrition and health conditions. National food supply in the form of proteins, and the disease environment, are other important determinants of nutritional status.

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1. Introduction

In sub-Saharan Africa (SSA), people's basic human needs are often not met and many suffer from malnutrition and poor health. It is often assumed that higher incomes for the poor are the most effective means for reducing malnutrition. The World Bank (1986) propagated the idea that income is the binding constraint for an adequate nutritional intake. There are many impoverished households in SSA spending a considerable fraction of their income on food. With income elasticities being high at low levels of income, a rise in income would translate into higher food consumption. Similarly, poor health is largely a result of poverty. African climatic conditions, for instance, are frequently blamed for the harsh disease environment. However, more health expenditures, both public and private, can help to prevent or cure disease. It is due to poverty that medical personnel, clinics, drugs and equipment, access to clean water and sanitation are lacking.

On the other hand, there is an influential theoretical literature highlighting the consequences of insufficient nutrition on labor income. In African economies, work often depends on physical strength and endurance and, therefore, on the nutrition and health of workers. Labor productivity provides the link for a causality running from nutrition and health to income (Leibenstein 1957; Strauss and Thomas 1998). Dasgupta (1997) used the nutrition-productivity link to explain poverty traps. At the macro level, Fogel (1994) argued that nutritional improvements increased life expectancy, helping to stimulate 19^{th} century industrialization.

In this paper, I study how sub-Saharan African countries ranked in terms of nutritional status, and whether nutrition and health conditions improved over time. I specifically analyze the influence of income, while paying special attention to endogeneity. The paper is structured as follows. The next section introduces the measure for nutrition and health status. In section 3, I clarify the time structure of the relationship between nutritional status and environmental factors including income. In sections 4 and 5, I present the data and address potential limitations. Sections 6 and 7 describe nutritional status cross-sectionally and over time. After discussing additional explanatory variables, the regression results are presented in section 9. The last section concludes.

2. Mean height as a measure of nutritional and health status

Anthropometry provides one of the best tools to measure nutritional and health status. Nutrition and health affect the physical development of children. To the human body, nutritional intake provides energy and nutrients, which are utilized for the maintenance of vital body functions (breathing, heart rate, etc.), fighting disease (raised body temperature, bodily wastes, parasites, etc.), physical activities and bodily growth (Srinivasan, 1992). The last acts as a buffer. Accordingly, the body fails to grow at a normal rate due to chronically insufficient intakes – in terms of both quantity and quality – and a high disease burden. At the population level, mean adult height can be considered as an indicator of nutritional and health status.

Final adult height registers height increments cumulatively from fetal origins to maturity. However, the early years of life are considered most crucial. Barker (1992), for example, posits a ‘fetal origins’ explanation, whereby deprivations in utero cause genetic adaptations. During the weaning period, children also have high energy needs, both quantitatively and qualitatively, and are highly vulnerable to infections caused by unhygienic conditions (Martorell and Habicht, 1986). For this reason, deprived children typically fall behind in the early years of life. As shortfalls in growth can rarely be caught up later, much of the variation in adult height is set by age 4 (Dahlmann and Petersen, 1977). Undernutrition can also influence physical development at puberty, delaying the adolescent growth spurt, slowing down body growth and lengthening the growth span (Bogin 1988). Some scholars believe that the prolonged growth phase usually balances out the lower growth velocity (Kulin et al. 1982). However, one can dispute this assumption. Figure 1 shows the growth pattern of girls in Cote d'Ivoire and Ghana (0-22 years) as compared to a healthy and well-nourished reference population. Growth retardation starts a few months after birth and continues to an age of 2-3 years. Growth velocity at age 4-11 years is roughly on par with the reference population. At age 11, body growth again falls behind, primarily because the reference population enters the adolescent growth spurt, which is delayed in malnourished populations. At approximately age 14, when the African girls enter puberty, catch-up growth can be observed, which in the case of Ghanaian girls is quite considerable. At age 18-20, the growth process comes to a halt.

What role does genetics play in determining heights? Genetics indeed strongly influences heights of individuals – it is expressed in the variance of individual heights that can be observed when individuals grow up under equal conditions. However, when mean heights of populations are considered, the 'noise' of individual genetics cancels. Evidence for similar growth patterns across populations comes from comparisons of healthy and well-nourished populations of different ethnic origins, which grow up under similar environmental conditions and attain similar mean heights.[1] In contrast, much larger height differences were found between rich and poor people of the same ethnic group (Habicht et al. 1974; Martorell 1984).

[1] African-Americans can be considered a well-off population of African origin. According to the most recent NHANES 1999–2002, 20-39 year old African-American women attained a height (164 cm), as tall as non-Hispanic whites (Ogden et al. 2004: 16). Similar conclusions were derived from well-off

Moreover, the genetic pool of a population does not vary over short periods such as 10-50 years. However, mean height does, if the environs have changed accordingly. In assuming that environmental conditions are the overwhelming cause for height differences across space and time, this study follows the predominant view of biologists and anthropologists, and adheres to the standpoint of the World Health Organization (Haas and Campirano 2006; WHO Multicentre Growth Reference Study Group 2006).

3. Modeling influences on height of birth cohorts from birth to maturity

This study follows a birth cohort analysis, in which nutritional status is examined from cohort to cohort. In the regression analysis, the dependent variable is the difference between mean heights of adjacent birth cohorts

(1) $$\Delta y_t = y_t - y_{t-1}$$

where y is mean height and t=1, 2, ..., 6 denotes the age groups 45-49, 40-44, ..., 20-24 for a given country. Five-year age cohorts are preferred here, as they reduce errors in the cohorts' composition due to age misreporting.[2]

It is important that the explanatory variables express changes in conditions under which the cohorts grew up. A straightforward approach is to take the average

Africans in Jamaica (Haas and Campirano 2006). Fiawoo (1979) reported a final height of 163.8 cm for privileged 18-year old girls in Accra/Ghana.

[2] Individuals who misreport their age will be assigned to wrong cohorts. Because the tendency to round off ages to numbers ending with 0 or 5 is more common among the lower educated strata (Ewbank 1981), some age cohorts disproportionately comprise poorer and shorter individuals, while these strata are missing in other cohorts. The biases in socioeconomic composition of cohorts also affect mean height estimates. Widening the age interval reduces the error considerably. For example, a 43-year old woman erroneously reporting an age of 40 years would be still assigned to the correct 5-year age group 40-44.

from annual values covering the complete span of the cohort's birth years. Then, analogous to (1), we can take first-order differences or alternatively, growth rates[3]:

(2) $$\Delta\bar{x}_t = \bar{x}_t - \bar{x}_{t-1}$$

It is a common assumption that environmental conditions during the first years of life determine final adult height whereas conditions at later ages are negligible. The equation that reflects this assumption is

(3) $$\Delta y_t = \beta_0 + \sum_{k=1}^{K} \beta_k \Delta\bar{x}_{k,t} + u$$

Thus, the difference in mean height between two adjacent age groups, say 35-39 year and 30-34 year olds, who were born in the 1960-65 and 1965-70 period respectively, would be explained by the change in say mean food supply between 1960-65 and 1965-70.

The specification in (3) ignores the fact that final adult height is a result of cumulative height increments from birth to maturity. In other words, it ignores the possibility that insults during childhood or adolescence can result in lower adult height. Brinkman, Drukker and Slot (1988) modeled the entire growth span, assuming that the influence of environmental circumstances at a given age is proportional to the share of growth typically accomplished at that age. They proposed the use of aggregated variables, where annual values are weighted according to typical Yearly Age and Sex Specific Increases in Stature (YASSIS). This approach, however, is problematic, as it is uncertain whether a determinant indeed influences body growth at

[3] For methodological reasons, the percentage change in GDP/c (PPP) will be used in the regressions. Heights are subject to a decreasing marginal product. Thus, an increase in income of $200 from a very low income, say £500, should have a larger effect on height than a $200 increase from a high level of income, say $1,500. Conceptually, a proportionate change in the differencing specification would correspond to a logarithm in a simple level specification.

all ages. Weighting annual values dilutes the variance of the explanatory variables. For instance, for a number of European countries Baten (2000) found that real wages during the cohort's first three years of life in fact had the largest impact on final height, while the weighting scheme reduced the explanatory power significantly.

The approach favored here is based on the following consideration. If changing environments affect body growth at a particular age so that a persistent imprint in final adult height is left, a regression should be able to reveal this systematic impact. We simply need to include into the regression those environmental changes that occurred at the various ages. Technically, the explanatory variables are shifted temporally ahead.[4] The general form of the regression equation is

$$\Delta y_t = \beta_0 + \sum_{k=1}^{K} \beta_{k,t} \Delta \bar{x}_{k,t} + \sum_{z=1}^{Z} \sum_{m=0}^{3} \beta_{z,t+m} \Delta \bar{x}_{z,t+m} + u \tag{4}$$

with K explanatory variables, which cover the cohorts' birth period only, and Z explanatory variables, for which we assume influences on final adult height from t to $t+3$. The regression coefficients $\beta_{z,t+1}$, $\beta_{z,t+2}$, and $\beta_{z,t+3}$ roughly correspond to the impact of environmental conditions during the first ($\Delta \bar{x}_{z,\,t+1}$), second ($\Delta \bar{x}_{z,\,t+2}$), and third ($\Delta \bar{x}_{z,\,t+3}$) 5-year periods after birth respectively. Precise insights into the temporal pattern are not feasible, as the cohorts cover 5-year age groups; uneven und superjacent influences within the cohorts become smoothed and are expressed as an average.

In equation (4), endogeneity of economic growth can arise from two sources. Firstly, nutrition in the cohorts' early years of life can positively correlate with the nutrition and health of the adult labor force (Fogel 1994). Assuming that a better nourished and healthier labor force is more productive, output increases. In this case, economic growth is endogenous and OLS would overestimate the actual influence of economic growth on nutritional status. Secondly, similar arguments apply, when the cohorts themselves enter the labor force, which may occur in *t+3* at the earliest. Their own nutritional and health status gives rise to the productivity link.

I follow an instrumental variable approach to address the endogeneity of GDP/ c in *t* and *t+3*. The empirical growth literature provides several candidates for valid IVs. From a neoclassical production function, it follows that output is a function of capital and labor, so that the investment rate, and the growth in the labor force, may predict economic growth. An important variable in the African context is the black market exchange rate premium, which is associated with distorting market practices and reduced economic growth (Barro and Lee 1994). The same set of IVs is used for economic growth in *t+3* but the time structure is adjusted accordingly. These IVs are a common choice in the literature (Pritchett and Summers 1996; Brinkman and Drukker 1998; Smith and Haddad 2000).[5]

At this point some remarks are in order. Note that the first-order difference estimation eliminates any time invariant factors such as genetics, climate related exposure to diseases, specialization in livestock farming, geography or, to some extent, economic inequality. This allows us to estimate a rather parsimonious

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[4] It is also possible to shift the dependent variable temporally ahead and to keep the time structure of the explanatory variables unchanged. For example, shifting the cohort's mean height by one period would give us the impact of the environment during late childhood.

[5] Recently, Acemoglu, Johnson and Robinson (2001) introduced settler mortality as an instrument for economic growth, arguing that a low settler mortality encouraged European settlements which in turn resulted in pro-growth institutions that persist until today. Note that settler mortality is not a valid instrument for a sample that consists entirely of sub-Sahara African countries. Results of the First Stage suggest that settler mortality is not significantly correlated with economic growth (p-value>0.3). The variation that can be explained by settler mortality must naturally be rather small. Settler mortality was constant, whereas economic growth was not – in the 1950s and 1960s, many African countries experienced substantial economic growth. Moreover, it is unclear exactly what the instrument picks up in the African context. In contrast to the proposed negative relationship, I found a weak positive correlation between settler mortality and economic growth.

regression model without running a large risk of omitted variable bias. Moreover, it is important to distinguish between the partial and total effect of economic growth (Pritchett and Summers 1996). Economic growth influences a number of variables which in turn influence nutritional status. Insofar as we include these intermediate determinants in the regression (such as daily protein supply or proxies for morbidity), the estimated coefficient reflects the partial effect only, that is, the effect of economic growth on nutritional status not already captured by the variables included. The total effect of economic growth including the effect of income mediated through the other variables is presumably larger. Finally, cohort studies demonstrated a correlation between adult height and health outcomes at ages above 40 (Waaler 1984; Barker 1992). The effect on labor productivity would then be expected to occur at the time when stunted and less healthy adults reach that critical age. The regression model presented here ignores this effect.

4. Data

The anthropometric data are taken from the Demographic and Health Surveys (DHS). DHS has conducted nationally-representative household surveys in developing countries, collecting a wide range of data in the areas of population, health, and nutrition (Macro).[6] For monitoring nutritional status, the questionnaires incorporated a section on anthropometry. From the first phase (DHS-I: 1984–89) and throughout, children younger than three and five years, respectively, were measured.

[6] Few DHS samples are self-weighting. Typically, subgroups constituting small proportions of the population were oversampled to improve the precision of estimates. Other groups in turn may have been underenumerated. Similiarly, some DHS surveys only measured women who had given birth to at least one child in three and five years preceding the survey instead of women in general. I applied sampling weights to correct for the sampling design.

In this study, however, we focus on adult height, to which DHS has increasingly extended its coverage. During the second phase (DHS-II: 1988-1993) DHS started to record the body stature of mothers, which became standard for all surveys of the third phase (DHS-III: 1992–1999). In the current phase (DHS+: 1997-present), the anthropometric section extends to all women between 15 and 49 years of age. Training and equipment for height measurements followed WHO guidelines (Loaiza 1997). Using measuring boards with headpieces, heights were recorded to the nearest millimeter. With heights of about 200,000 adult women in 28 African countries, the DHSs offer an excellent anthropometric database (Table 1). Varying typically between 2,000 and 5,000, the surveys comprise 4,230 observations on average.

From the DHSs, I calculated the mean height of each 5-year age groups (20-24, 25-29, …, 45-49). Women younger than 20 years were excluded from the analysis, because many of them had not attained their final height at the time of the survey. On the other side of the age range, the age of 50 years is considered the time when, in the normal process of ageing, women begin to loose stature rapidly (Cline et al. 1989). Overall, the coverage of countries represents a significant extension to existing anthropometric collections such as that of Eveleth and Tanner (1990), and the enormous number of individual height measurements should give confidence to the mean height estimates.[7]

[7] Because of the large sample size, the standard error of the mean is rather small. Taking the median size of a 5-year age cohort with 750 observations, for example, would result in a 95% confidence interval of roughly eight millimeters.

5. Selection effects and limitations

Infant and child mortality selectively favor the tall over the short (Pelletier 1994; 1998; Pelletier and Frongillo 2003). As only the surviving population was measured by the survey, mean height - as a representation of health conditions at the time of childhood - will be biased upward. Estimates of the effect of income growth on nutritional status will also be affected. In periods of high income, a higher proportion of short children, who would have died under poorer conditions, are able to survive. Hence, the presence of child mortality, which, like height, is affected by income, will tend to bias downward the estimated effect of improvements in income.

How severe is the survivorship bias? Alter (2004) modeled this effect using plausible assumptions about the responses of height and mortality to changes in diet and diseases. His results suggest that the extent of survivorship bias on observed mean height is rather small, totaling about one centimeter, when changing the disease scenario from pre-industrial to modern mortality patterns (that is, from 50% to 100% surviving to age 20). This roughly agrees with studies on Africa. For instance, in a longitudinal study of children (0-5 yrs) in two Gambian villages, an environment with extremely high mortality, Billewicz and McGregor (1982) found a difference of approximately two centimeters between girls who died and those who survived.

Under normal conditions, mortality of young or middle age women is low and biases thereof are rather negligible. In African countries, however, the HIV/AIDS pandemic has caused a sharp rise in adult mortality. Several studies found that HIV infection tends to be more common in urban, wealthy and better educated individuals (see the overview in Glynn et al. 2004). As the selection process will be tied to age and birth cohort given the historical progression of the disease, cohort to cohort comparisons of mean heights could be biased. Table 2 summarizes those studies that report average body stature according to HIV status. As one would expect, HIV-positive women tend to be slightly taller. The extent of the bias also depends on the survival rate in addition to the prevalence rate. The former is probably higher for the more privileged. The overall effect is therefore not conclusive. In the Kagera, Tanzania Health and Development Survey 2004, for example, adult mortality in a 10-year-period (not necessarily entirely due to HIV/AIDS, but nonetheless a high figure due to the disease) is not significantly correlated with adult height (World Bank). Similar evidence comes from the DHSs. It is possible to compare the mean height of 25-29 year olds with that of 30-34 year olds in surveys of the same country conducted five years later. Both cohorts refer to the same birth period. If there is a strong bias due to HIV/AIDS, one would expect to find systematically shorter women in the second survey, and even more so, a higher prevalence rate. However, this is not the case (Moradi 2005).

DHS has not collected the height of men. How informative are samples of women for the nutritional status of the entire population? Height trends of the genders need not necessarily correspond. One reason for divergence is that the intra-household allocation of high-quality nutrients and medical resources can shift in favor of one gender (Moradi and Guntupalli forthcoming). SSA was found to be a region with a relatively favorable nutritional status for women as compared to men (Klasen 1996). Nevertheless, boys and girls living in the same household are subject to many similar environmental conditions. Deviations from sexual dimorphism in stature can therefore be expected to be much smaller than height differences over space and time. In a cross-section of African populations, Gustafsson and Lindenfors (2004) found a strong and highly significant correlation between mean heights of the genders

(R^2=0.96).[8] It is also possible to examine changes over time for two African countries, Cote d'Ivoire and Ghana. As shown in Figure 2, trends between males and females in Cote d'Ivoire correspond very closely. Improvements in nutritional status can be observed for both males and females, which, however, slowed down in cohorts born in the mid-1950s. In Ghana, gender differences are more pronounced. Though heights of men and women increased 1940-1955, the slope is significantly steeper for women suggesting that there were somewhat greater improvements for females during that time. Moreover, falling heights affected females about five years earlier.[9] Nevertheless, differences or changes in gender dimorphism are unlikely to delude conclusions.

6. Nutritional status of cohorts born in the 1960s and per capita income

For assessing the nutritional status in the cross-section, I examine mean heights of 10-year age cohorts who were born in the 1960s and compare these with historical populations and other developing countries.[10] I find that the nutritional status of African women was remarkably high (Figure 3). Even in Madagascar and Comoros, where the shortest women live, mean height was well above 152 cm, the height reached by underprivileged female Dutch orphans and factory workers born in 1849

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[8] The relationship was estimated as "Male Height=-0.85+1.073*Female Height". Number of populations: 40.

[9] When comparing the experience of Cote d'Ivoire with that of neighbouring Ghana, it is the nutritional status of Ghanaian men which diverged most. In contrast, there is a striking agreement in the height of women born 1940-1955 in the two countries.

[10] The 1960s were used as a benchmark, because this was the decade that DHS's adult heights covers best. The DHSs of Central African Republic, Namibia and Senegal, for example, were carried out in 1994/95, 1992 and 1992/93 respectively. In these cases, the births of the youngest adult cohorts (age group 20-29) are centered in the 1960s. In contrast, more recent DHSs like Malawi 2000, Mali 2001 and Mozambique 2003 cover both the 1960s and 1970s (see also the height series in Figure 4 to Figure 8). In contrast, when using the most recent adult cohort (or selecting the same age groups), base years would differ between the countries.

(van Wieringen 1972). Furthermore, most African women were taller than the 155 cm of women born in pre-famine 1830 Ireland (Oxley 2004). In the majority of countries, heights also exceeded the 158 cm reached by Bavarian women born between 1865 and 1879 (Baten and Murray 2000). In Chad and Senegal, women were almost as tall as modern US citizens (Kuczmarski et al. 2002). The nutritional status of Africans also compared well with other developing countries. African women, for instance, outgrew their counterparts in India and Colombia, who attained a mean height of 151 cm and 157 cm respectively (Meisel and Vega 2007; Moradi and Guntupalli forthcoming). To conclude, African women born in the 1960s were remarkably tall. Nutritional status can be considered some 20-100 years behind OECD countries.

Using income as a measure of living standards one would come to a different conclusion. As shown in Figure 3, more than half of the countries in our sample had a GDP/c lower than that realized by the US in 1820. Except for Gabon, Guinea, and Namibia, all countries were well below US GDP/c in 1870 (Maddison 2001). Additionally, the ranking of the countries differs substantially. Burkina Faso and Mali, for example, ranked among the poorest African countries in terms of per capita income, although mean heights suggest that nutritional conditions may not have been as poor. Quite the contrary can be observed in Madagascar and Mozambique. Overall, there is no significant correlation between mean heights and GDP/c (p-value: 0.69).

There are several explanations as to why anthropometric outcomes in Africa deviate from the expected height-income relationship. In the semi-arid and arid regions of Africa, livestock farming is a widespread activity, providing an important source of high-quality proteins that favor body growth in particular. Moradi and Baten (2005), for example, found cattle density to be a significant predictor of height differences within African countries. The like is evident at the country level; the five countries ranking highest in terms of nutritional status are Sahel countries with high cattle holdings. Specialization in animal husbandry, however, is not associated with income. The limited influence of GDP/c on nutritional status can also be attributed to the common deficiencies of income as a measure of living standards. The two richest countries in our sample are a case in point. In Gabon and Namibia, oil and mining, respectively, inflated GDP, but with a large amount of wealth going to foreigners and with very unevenly distributed income. In fact, the majority of the population in both countries lives in pronounced poverty and national income fails to translate into corresponding nutritional and health levels.

However, such historic legacies are changing, and it is interesting to note that the correlation between (logs of) GDP/c measured at the birth of the cohorts and their mean height increases over time, though correlation does not reach statistically significant levels (p-values>0.2).[11]

7. Development of nutritional status

Which inferences can we draw from changes in mean height? Height trends provide information on the development of nutritional status. Any decrease in mean height indicates a severe crisis. Even stagnating heights could be considered as an indication of nutritional problems since the spread of western medicine, knowledge of hygiene, and medical care should result in lower energy expenditures, therefore leaving more energy for growth (Komlos 1999; Baten 2003). Thus, a stagnation of mean height may primarily occur if the food consumption of a sufficiently large number of individuals decreases quantitatively or qualitatively.

The development of heights in SSA stands in striking contrast to the good state in the cross-section. For a number of countries, either a downward trend or no clear trend can be observed (Figure 4 and Figure 5). Heights decreased at about one and a half centimeters in Chad, Guinea, Namibia, and Zimbabwe. In Mozambique and Niger, the younger cohorts attained a stature one centimeter shorter than the previous generation. In Benin, Comoros, Ethiopia, and Malawi, mean heights are nearly constant throughout the entire period. For another group of countries, nutritional status followed an inverted U, indicating no sustained progress in health and nutritional conditions (Figure 6, Figure 7). Improvements mainly came to a halt in the birth cohorts of 1960s, with subsequent mean heights moving down to the level of 1950 birth cohorts. Only in Burkina Faso, CAR, Nigeria and Togo did a height advantage over the past exist. There are only a few sub-Sahara African countries showing a clear upward trend in nutritional status (Figure 8). Kenyan women born in 1975 were two centimeters taller than their counterparts born two decades before. In Cote d'Ivoire, the upward trend is weak although continuous. Tanzania and Senegal achieved impressive gains in height at one centimeter per decade. However, growth came to a halt in the 1960s and the mean height of subsequent birth cohorts declined so that these countries are more likely to follow the inverted U experience of the great bulk of African countries.

I conclude that although many African countries have taken steps forward in the second half of the 20th century, eventually almost the entire Southwest and Southeast African went into a nutritional or health crisis. With this development, the sub-Saharan region appears as an important exception to the worldwide trend of upward-

[11] This is consistent with results from the panel analysis in section 9 where economic growth was found to influence changes in height significantly positively - ultimately the levels should reflect this pattern.

sloping heights indicating that the second half of the 20th century cannot be treated as a period in which progress in essential human needs took place universally.

The height series broadly follow the path of economic development. Sub-Saharan African economies did well in the 1950s and 1960s. In the 1970s, performances varied but in general, economic growth decelerated. In the 1980s, most African countries experienced a severe and protracted economic crisis with predominantly negative growth rates in per capita income. From this rough description, it appears that the decline in nutritional status precedes recession by about one decade.

8. Determinants of temporal variation in heights

In this section, I discuss explanatory factors other than economic growth that will serve as control variables. National food availability is one parameter of adequate dietary intake. I include protein supply in the regression, stressing the quality aspect to a larger degree.[12] Especially high quality foods like meat, fish, eggs, and milk contain large amounts of proteins. Moreover, protein-rich foods tend to contain other important nutrients like calcium, iron and phosphorus, all of which are critical inputs for muscle and bone formation and therefore favor bodily growth in particular.

Nutritional status is not only determined by food intake but also by nutritional needs. Diseases inhibit the absorption of nutrients in food and put a strain on children's body growth. Unfortunately, reliable data on morbidity and health inputs are scarce. Following Schneider (1996) and Weir (1993) and the biological literature

[12] In fact, growth rates of calorie and protein supply are highly correlated (R^2: 0.80). In the cross-section, however, the correlation is rather weak, and here, results point to proteins as the more powerful predictor of mean height (Moradi 2005).

(Sobral 1990; Barker 1992; Schmidt, Jørgensen and Michaelsen 1995), I use infant mortality as a proxy for the epidemiological environment to which infants and children are exposed. However, even though widely applied, this approach is not unproblematic. Strictly, mortality is not a cause of undernutrition; rather, both are determined simultaneously (Pelletier 1994; Schroeder and Brown 1994). Moreover, as discussed above, decreasing mortality could turn out to be less selective - a larger number of short children survive, tending to lower mean height. As there is only one variable designated to describe partly opposed processes], it is only possible to obtain the overall effect.

Increases in family income need not necessarily translate into more resources available to children. It is important to consider changes in intra-household allocation, which I proxy with total fertility rate. Fertility is a choice between the quantity and quality of children (Becker 1960). Parents with fewer children have chosen to invest more in quality, and as such in the nutrition and health of their children. Therefore, decreasing fertility should be associated with rising mean heights (Weir 1993). A variable which allows us to observe investments into children directly is the education level attained by cohorts. Education also serves as a proxy for the provision of public goods besides schooling, so that we would expect a positive impact of education on nutritional status.

In SSA, the great majority of people derive their living from agriculture. Rain-fed cropping systems are predominant, making rainfall an essential input in agriculture (Benson and Clay 2000). In particular, subsistence farmers, small tenants and landholders, and pastoralists all rely on rainfall. A shortfall in rain causes their endowment of food and income to fall while food prices simultaneously rise. Thus, their food security depends on the quality of each rainy season. Large landowners and city dwellers, in contrast, are less vulnerable to climatic shocks. Consequently, droughts have distributional effects that are not accounted for by economic growth. Severe droughts in 1968-1973 triggered famines in Ethiopia and the Sahel (Dinar and Keck 2000). In 1974-1985, a second wave of droughts followed; from the 28 countries in our sample, 21 countries experienced more than two consecutive years of drought. In addition to short-term shocks, the Sahel countries encountered a systematic decrease in rainfall; precipitation in the period 1961-90 was 10-20% lower than the three preceeding decades (Hulme 1992).[13]

Civil wars are another all too frequent tragedy in SSA with detrimental effects on nutrition and health. Farmers are prevented from sowing and harvesting on time, or, fleeing conflict, they abandon their fields altogether. Blocked roads and partitioning disrupt the allocation of goods and foods. The epidemiological environment is also likely to deteriorate. Capacity cuts and the destruction of health facilities routinely undermine health care services. Refugee movements and poor hygiene are fertile grounds for the spread of infectious diseases (Kalipeni and Oppong 1998). During conflicts, military expenditures increase considerably, crowding out health care investments. These adverse effects make it likely that cohorts born in times of civil war suffer from deteriorating nutritional status. In our sample, the most war-torn countries are Chad, Ethiopia, Mozambique, Nigeria, Uganda, and Zimbabwe.

Finally, I include urbanization. Indicating a transition from a traditional to a modern industrial society, the process of urbanization is associated with an increased complexity in the value added chain (Tiffen 2003). Therefore, urbanization can

[13] It would be ideal to follow the conceptualization of agricultural droughts, which refer to situations in which soil moisture is insufficient to meet the needs of the plants (Glantz 1987). For example, apart from total rainfall, the right distribution during the different stages in the crop's development is equally

complement GDP/ c, e.g., when primary commodity booms inflate national income without a broad diffusion of benefits like in Gabon, Namibia, Nigeria, or Zambia. Moreover, urban areas provide better housing, health services, employment opportunities, access to public goods like water and sanitation services, among others. On average, city dweller enjoy an height advantage (Loaiza 1997). Urbanization could simply reflect an increasing share of the population that benefits from these amenities.

9. Regression results

Table 3 reports the OLS determinants of temporal variation in mean heights. Regression OLS (1a) contains the complete set of explanatory variables, which, by excluding jointly insignificant variables, is then reduced to OLS (1b). In contrast to the lack of correlation between GDP/c and heights in the cross section, I find a significantly positive impact of growth in GDP/c on the development of mean heights. Besides a positive effect of economic growth in the cohort's early years of life (in *t*) an additional positive effect can be found in *t+3*, which roughly corresponds to the time of puberty.

Acknowledging the effect at puberty is important to avoid misinterpretations. In many African countries, the development of mean height followed an inverted U, with trend reversal often occurring in cohorts born in the mid-1960s (Figure 6, Figure 7). From these trends, one cannot infer that environmental conditions started to deteriorate in the 1960s. The significant coefficient of economic growth in *t+3* indicates instead that the crisis of the late 1970s and 1980s, and its influence on body growth at puberty must be considered partly responsible for the fall in mean adult

important. Though the concept of agricultural droughts does better describe conditions eventually heights registered in the mid-1960s birth cohorts. It is possible that the severe economic crisis of the 1980s gave rise to the influence at puberty. When I restrict the sample to cohorts born before 1965, I find the impact in *t+3* reduced (though the effect in *t+2* becomes stronger).

The impact of economic growth is substantial. Growth in GDP/ c between 5-year age cohorts averaged 4% and varied, with a standard deviation of 12.4, between -27% and 36%. Thus, a difference in economic growth on the order of one standard deviation would add 0.1 cm to the mean height of the cohort in their infanthood (the impact in *t*), as well as to the cohort at the age of puberty (the impact in *t+3*). Under a scenario of an annual growth rate of 2.5%, a country's mean height is predicted to increase by one centimeter over 20 years.

In the first two regressions OLS (1a) and (1b), unavailable data on protein supply and urbanization restrict our analysis to cohorts born 1963-84. I exclude these variables in OLS (2a) and (2b), so that the sample increases in size and covers cohorts born in the 1950s. As a result, the impact of economic growth is increasing in significance. Moreover, the positive influence in *t+3* crossed over to *t+2*. In FE (3), I ran a country fixed effects regression in order to control for country-specific, deterministic time trends in height. Under this specification, the estimated impact of income increases slightly. The country fixed effects are significant at the 10% level (p-value: 0.07). In Namibia and Zimbabwe, for example, the development of mean height was consistently worse than expected. Mean heights were *ceteris paribus* decreasing by 0.3 centimeter per 5-year cohort. One may speculate whether social and economic discrimination against the black majority in both countries might be the

leading to lower yields, no data exists for our purposes.

reason that nutrition and health deteriorated despite substantial economic growth (Figure 4).

The importance of economic development is overwhelming. When controlling for other factors only the proxy variables of nutrition and health are significant predictors of height. Food supply in the form of proteins influenced nutritional status significantly positively, in line with studies of child malnutrition (Brinkman and Drukker 1998; Smith and Haddad 2000). A ten percent rise in protein supply over a 5-year period would increase mean heights by about 0.2 cm. Like economic growth, food supply fits the overall height pattern particularly well. In the late 1960s, growth rates in per capita food availability tended to decrease in most African countries. In OLS (1b), the infant mortality rate also has the expected negative sign, so that declining infant mortality was associated with increasing mean heights. In many African countries, infant mortality rates decreased almost linearly (though with different slopes), and paces were only slowing down slightly in the 1970s. Therefore, taking infant mortality as a health indicator, health cannot explain the overall trend of net nutritional status in SSA for the period 1950-1980.[14]

Other variables do not add much explanatory power (OLS (1b) and (2b), Table 3). The education the cohorts attained has the expected positive sign, but it is not significant at conventional levels (p-value: 0.12). Micro studies of undernutrition, in contrast, regularly found a positive effect, notably of the mothers' education, which increases the likelihood of good childcare practices. Accurately modeling this effect at the macro level, however, is extremely difficult. I would also argue that, in micro studies, education frequently serves as an indicator of social status which leads to overestimating the true influence of education. The civil war variable is also insignificant. Clearly, people suffer in conflicts, though the effects appear to be sufficiently accounted for by the collapse of the economy. On average, civil wars are associated with a 10% fall in GDP/ c, suggesting that nutritional status decreases during civil wars. Finally, fertility and urbanization cannot explain the development of mean heights in SSA, and although rainfall has the expected positive impact in OLS (2a), it is not very robust.

The link between nutrition and health on one hand, and labor productivity on the other, possibly makes income growth endogenous. In this case, OLS coefficients would be upwardly biased. I therefore instrumented economic growth in both, *t* and *t+3* in TSLS (1), Table 4. The point estimates are similar to the OLS results. The size of the TSLS coefficient for income growth in *t* exceeds the one obtained in OLS (2b) and FE (3). The influence is significant at the 10% level. The effect in *t+3* is also positive, but slightly lower and insignificant. This result was obtained because our IVs are less powerful for economic growth in *t+3*. The IVs do not have a highly significant impact on economic growth (p-value: 0.06), and the lower efficiency of TSLS translates into large standard errors. Accepting the exogeneity of economic growth in *t* and running the TSLS again, with economic growth endogenous in *t+3* only, increases the sample size (TSLS (2), Table 4). Though the IVs comfortably pass the relevance test (p-value: 0.00), significance does not increase to conventional levels. Nevertheless, the size of the TSLS coefficient is similar to that of the OLS. This confirms the Wu-Hausman test indicating that the null of exogeneity of economic growth cannot be rejected.

There are factors which can dwarf the case of endogeneity at the macro level. The nutritional situation of laborers and children need not correlate very strongly.

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[14] Because first-order differences in infant mortality rates do not vary much within countries, infant

Given the nutrition-productivity link, one would expect a utility maximizing household to treat its members unequally (Behrman 1997; Dasgupta 1997). In fact, the consumption of household members whose labor contributes to the household's income might be rather inelastic. Furthermore, it is doubtful whether total value added, as contributed by a single 5-year age group of juveniles (in $t + 3$), is significant enough that increased labor productivity – solely caused by taller stature – measurably influences economic growth. Also, the cohort's lower health status may not affect productivity instantly. There is overwhelming evidence that adult height is a significant predictor of morbidity and mortality at ages above 40, so that productivity effects may not yet have materialized.

10. Conclusions

In this paper, I studied nutritional status in sub-Sahara African countries cross-sectionally and over time. Taking population mean height as an indicator and aggregating data from more than 200,000 women in 28 countries, I found that nutritional status of cohorts who were born in the 1960s was mostly in a good state. The tall stature of adults contrasted with the extent of income poverty in SSA, and no correlation could be found between GDP/c and mean height within the sample of African countries. I argued that national income in levels poorly reflect nutritional conditions in SSA.

The development in mean height over time pointed to deteriorations in nutritional status. In a number of countries, mean height stagnated or decreased. Even though several African countries made some improvements, eventually the entire

mortality becomes insignificant in the country fixed effects specification in FE (3).

Southwest and Southeast regions of the African continent went into nutritional crisis. Overall, SSA represents an important exception to the trend of upward-sloping heights present in almost all other regions of the world in the 20^{th} century.

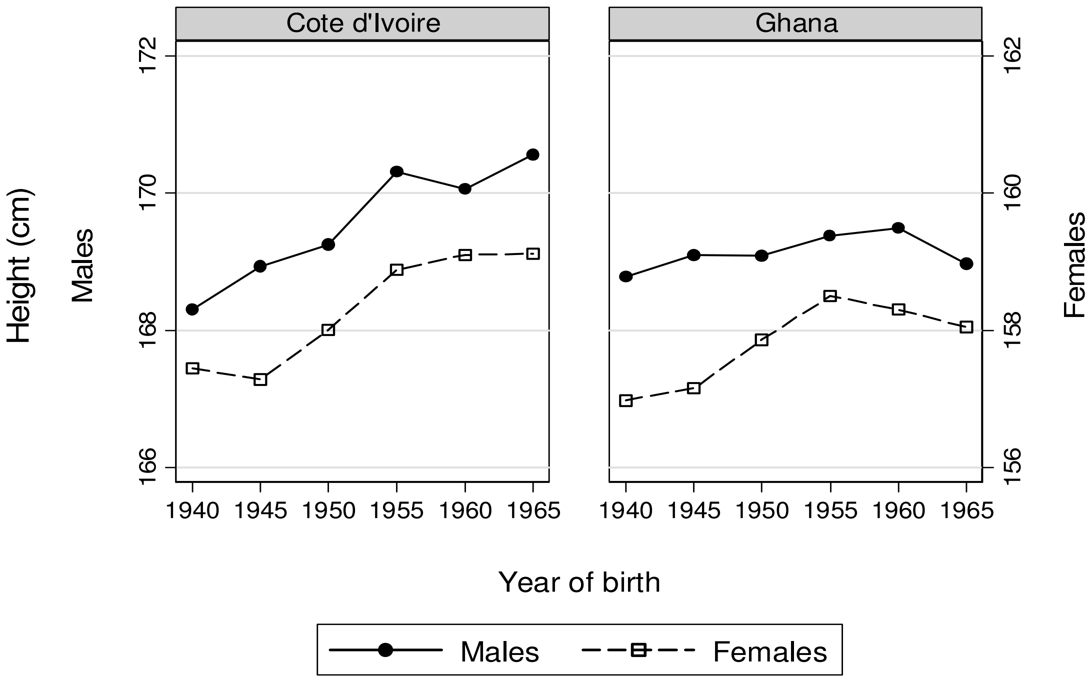
In a regression analysis, I tested the explanatory power of economic growth and several other determinants on temporal height variations, modeling the entire growth phase, from birth to maturity. The results indicate that economic development influenced the physical growth process in a way that had a lasting impact on final adult height. Two distinct age periods were found to be particularly responsive: (1) the first years of life and (2) puberty. The impact of economic growth during infanthood is in line with the findings of most anthropometric studies. More surprising is the effect at puberty which appears to be peculiar to sub-Sahara African societies. Acknowledging this effect is important. Firstly, it implies that the economic crisis of the late 1970s and 1980s played a role for the trend reversal in mean heights occurring in cohorts born in the mid-1960s. Secondly, the effect at puberty may turn out to be crucial to understand the tall stature of adults in SSA. Puberty represents a time window that allows for catch-up growth. This finding calls for more research. Most studies focus on 0-5 year olds; adolescents, in contrast, are an under-researched group. What environmental conditions are specifically responsible for the effect at puberty? For instance, in this age group, the health environment would be expected to play a smaller role. Does access to nutrition and health change in adolescence and if so, why? What instantly comes to mind is that adolescents often contribute to household income and can therefore claim a larger share. In the regression analysis, I took into account the endogeneity of income which is plausible if nutrition and health are strongly linked to productivity which in turn influences income. However, point estimates of a TSLS estimation were very similar to OLS (even though statistical significance was not reached). Endogeneity in the age groups 0-20 years is therefore not a likely source of bias.

In most African countries economic growth was very effective in improving nutrition and health conditions. Thus, at the end, rising incomes indeed translated into a higher consumption of goods such as food, basic sanitation, clothing, shelter and medical care – all of which contributed to improved nutritional status. This result has implications for one of today’s most pressing problems. In the fight against undernutrition, a promising approach would be to bring African countries back to the path of economic growth that they left in the 1970s.

Figure 1: Height-for-age Z-Scores of girls (0-22 years) in Cote d'Ivoire and Ghana

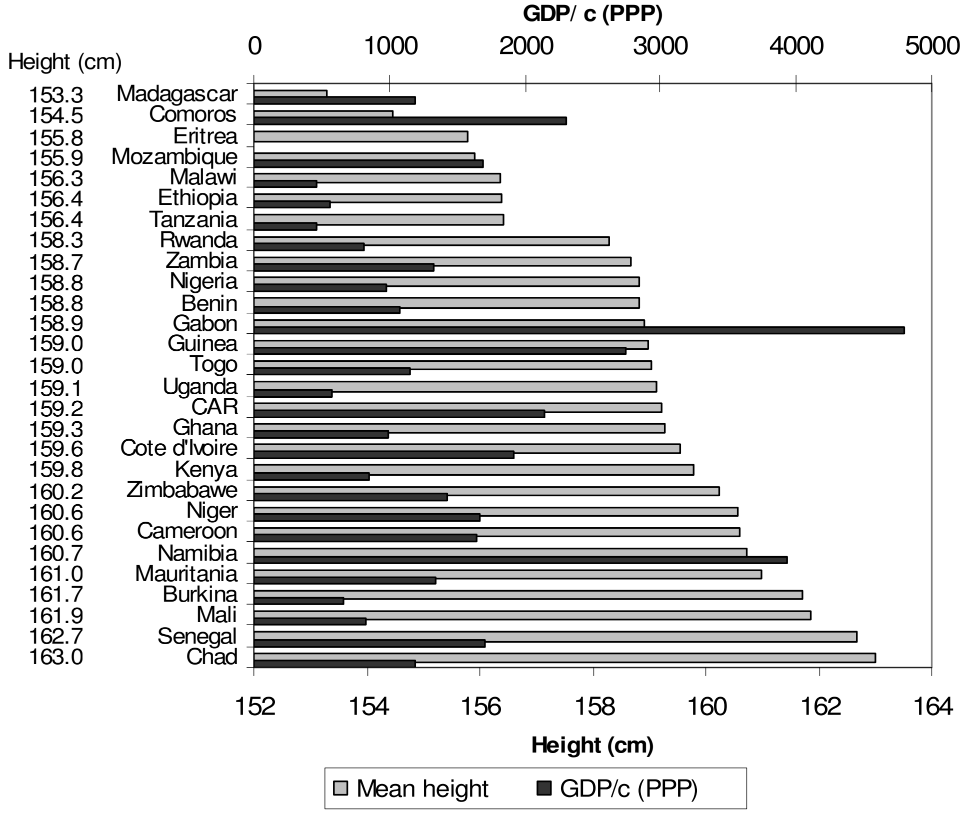
Note: Height-for-age Z-scores measure the distance, in units of standard deviations, between the population's mean height and the median height of a healthy and well-nourished reference population of equal gender and age. The data is drawn from the Living Standard Measurement Study surveys GLSS 1988/89 and CILSS 1985/86/87/88 (World Bank). N(Ghana)=4192. N(Cote d'Ivoire)=10901.

Figure 2: Height trends of the genders in Cote d'Ivoire and Ghana



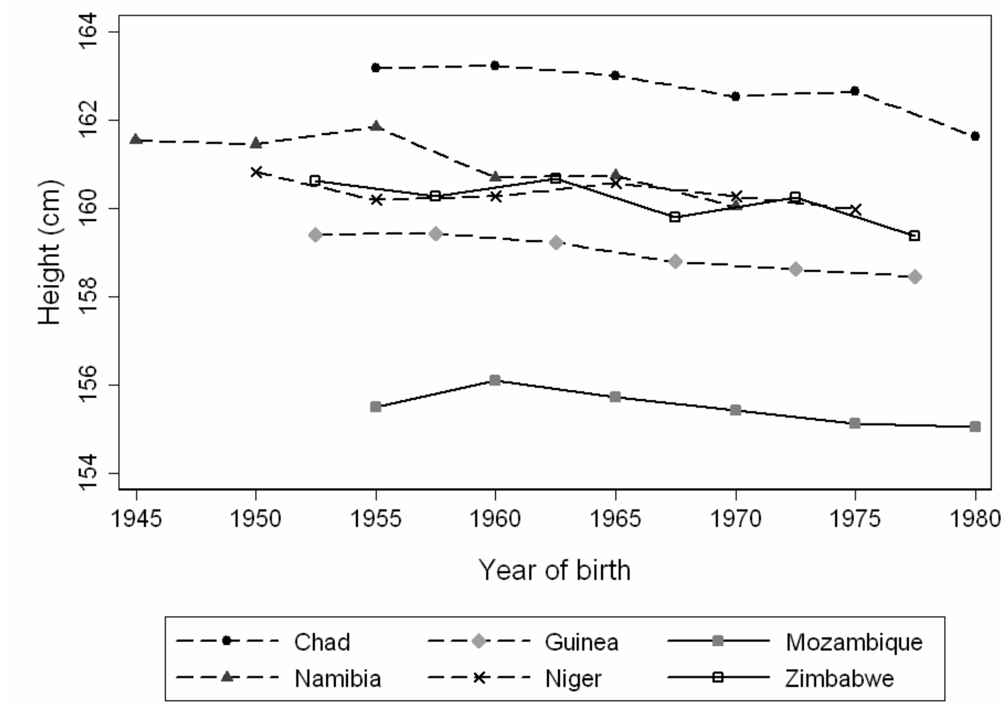
Note: The data is drawn from the Living Standard Measurement Study surveys GLSS 1988/89 and CILSS 1985/86/87/88 (World Bank). About 40% of the individuals in the CILSS and 60% in the GLSS survey were remeasured in a second round. Inconsistencies between the first and second rounds (sex, age > 5 years, height > 10 cm) as well as extreme outliers were excluded; remaining minor deviations were averaged. In total, the Ivorian (Ghanaian) mean heights are based on 9484 (8138) native born individuals between 20 and 49 years of age.

Figure 3: Mean height of women and GDP/c, 1960s



Note: GDP/c figures are averaged over 1960-1969, so that they roughly correspond to the time when the 10-year age cohorts were born. The data was taken from Penn World Tables 6.1 (Heston, Summers and Aten 2002). US GDP/c (PPP) in 1820, 1870, and 1913 was approximately 1360, 2650, and 5740 (Maddison 2001).

Figure 4: Decreasing mean heights



Note: Birth cohorts are based on 5-year age groups (45-49, 40-44, ..., 20-24). The year of birth corresponds to the cohort mean and was assigned to the nearest 2.5-year segment. Cohorts with less than 100 individuals were excluded.

Figure 5: Stagnating mean heights

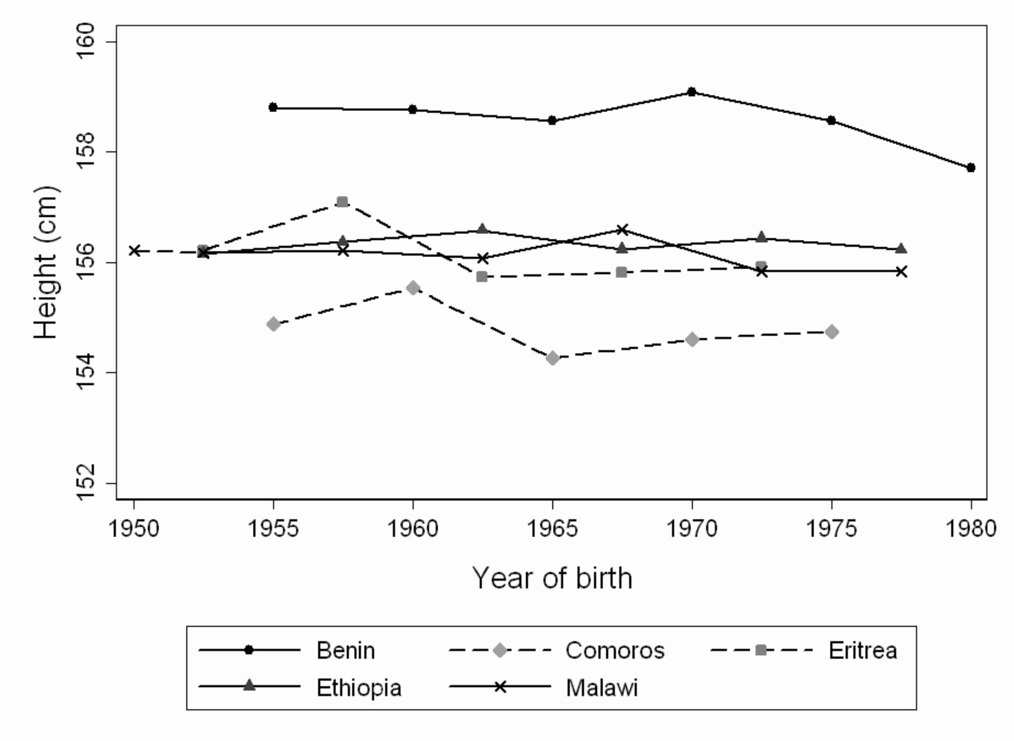


Figure 6: Height trends following an inverted U (1)

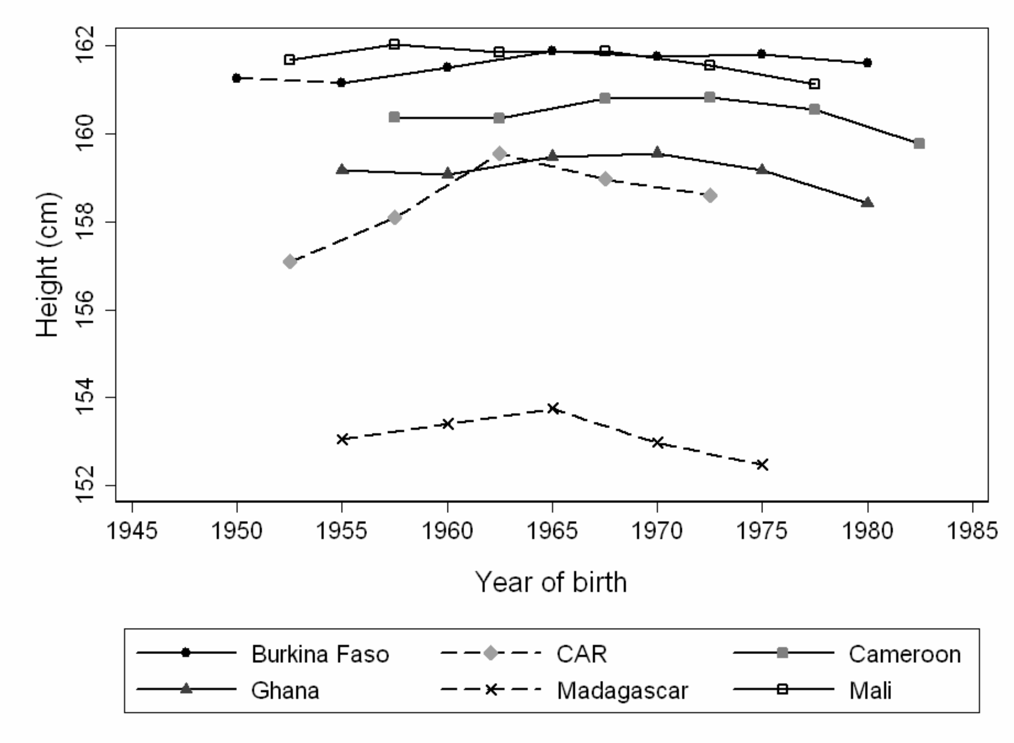


Figure 7: Height trends following an inverted U (2)

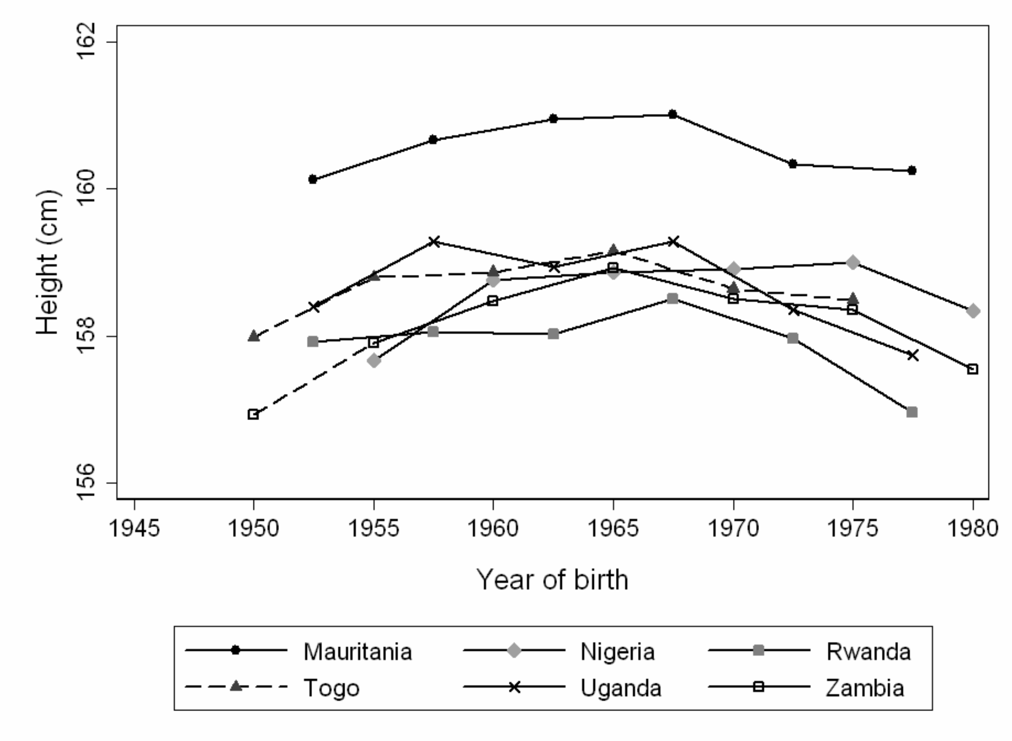


Figure 8: Increasing mean heights

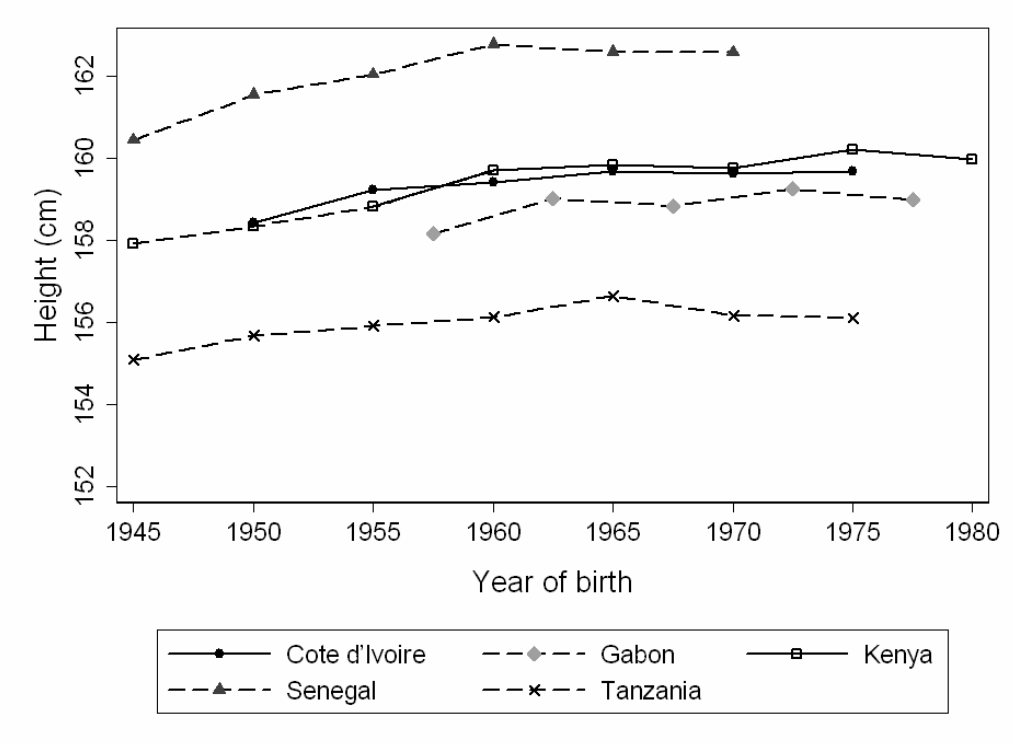


Table 1 Anthropometric data in the DHS-surveys

Country	Date of survey	Number of women (Age group 20-49)
Benin	1996 & 2001	2400 & 4957
Burkina Faso	1992/93 & 1998/99 & 2003	3459 & 3569 & 9547
Cameroon	1998 & 2004	1609 & 3890
CAR	1994/95	2050
Chad	1996/97 & 2004	3940 & 3193
Comoros	1996	835
Cote d'Ivoire	1994 & 1998/99	3017 & 2221
Eritrea	1995	1836
Ethiopia	2000	11656
Gabon	2000	2359
Ghana	1993 & 1998 & 2003	1785 & 2216 & 4374
Guinea	1999	3401
Kenya	1993 & 1998 & 2003	3425 & 3378 & 6010
Madagascar	1997	2580
Malawi	1992 & 2000	2495 & 10152
Mali	1995/96 & 2001	4438 & 9833
Mauritania	2000	5910
Mozambique	1997 & 2003	3158 & 9253
Namibia	1992	2381
Niger	1992 & 1998	3569 & 3466
Nigeria	2004	5737
Rwanda	2000	7544
Senegal	1992/93	3178
Tanzania	1992 & 1996	4711 & 3959
Togo	1998	3470
Uganda	1995 & 2000/01	3401 & 5118
Zambia	1992 & 1996 & 2001/02	3386 & 4084 & 5762
Zimbabwe	1994 & 1999	1948 & 4219
Total: 28 countries	1992 – 2004	198879

Note: Based on surveys that were available by March 2006. We excluded the age group 15-19, because some of the individuals were still growing at this age. We also excluded height measurements departing from the birth cohort mean by more than three standard deviations.

Table 2: Differences in mean height according to HIV status

Sample	HIV/AIDS Prevalence	Mean height according to HIV status		Source
		Non-infected	Infected	
Pregnant women in four antenatal clinics in Dar Es Salaam, Tanzania, 1995-97; N=13760	13.1%	155.1 cm	155.7 cm	(Villamor et al. 2002)
Mothers who gave birth 4 to 20 wks prior and sought immunizations for their infants in a government health clinic in a rural part of KwaZulu Natal Province, South Africa, 2001-02; N=61	27.8%	158.2 cm	159.8 cm	(Papathakis et al. 2005)
Women registering for antenatal care at a maternity hospital in Harare, Zimbabwe, 1996–97; N=1653	31.5%	"No significant differences"		(Friis et al. 2002)

Table 3: OLS-Determinants of temporal variation in heights

Age groups included (Birth cohorts: ...-1979/84)	20-39 1963/69	20-39 1963/69	20-39 1963/69	20-44 1953/59	20-44 1953/59	20-44 1953/59
Dependent variable: Δheight (cm)	Mean [standard dev]	OLS (1a)	OLS (1b)	OLS (2a)	OLS (2b)	FE (3)
Constant		0.930 (0.95)	-0.487*** (-3.63)	1.997*** (3.88)	2.333*** (5.13)	1.963** (3.75)
ΔProtein supply/ c (percentage change)	-0.51 [6.74]	0.014** (1.97)	0.018*** (3.02)	—		
ΔIMR, females	-10.78 [3.99]	-0.016 (-1.29)	-0.019* (-1.67)	-0.011 (-1.04)		
ΔCohort's years of schooling (percentage change)	15.87 [17.53]	0.003 (1.48)	0.004 (1.58)	0.001 (0.35)		
ΔRainfall (percentage change)	-3.38 [8.55]	-0.003 (-0.07)		0.008* (1.61)		
Civil war	0.11 [0.27]	0.100 (0.53)		-0.061 (-0.42)		
ΔTotal fertility rate	0.05 [0.16]	0.034 (0.10)		0.221 (0.77)		
ΔShare of urban population	2.90 [1.88]	0.011 (-0.37)		—		
Mean year of birth	73.52 [4.30]	-0.019 (-1.51)		-0.032*** (-4.64)	-0.035*** (-5.48)	-0.030*** (-4.74)
ΔGDP/ c_t (percentage changes)	3.95 [12.42]	0.009*** (2.69)	0.009*** (2.79)	0.008** (2.08)	0.009** (2.56)	0.011** (2.47)
ΔGDP/ c_{t+1}	-0.61 [14.17]	-0.003 (-0.81)		-0.006* (-1.81)	-0.006* (-1.72)	
ΔGDP/ c_{t+2}	-3.57 [13.48]	0.001 (0.29)		0.005 (1.65)	0.005 (1.50)	0.006* (1.98)
ΔGDP/ c_{t+3}	-4.06 [11.87]	0.009** (2.69)	0.010*** (3.32)	0.007* (1.79)	0.008** (2.00)	0.014*** (3.68)
Country fixed effects (p-value)						0.07
N observations (countries)	72 (27)	72 (27)	72 (27)	117 (27)	117 (27)	117 (27)
R^2-adj.		0.23	0.25	0.34	0.34	0.36

Note: Birth cohorts with less than 100 individuals were excluded. t-statistics in parentheses; coefficients significant to the 10%/ 5%/ 1% level are marked with */**/***.
The data for the explanatory variables were taken from several sources. The figures on protein supply, available from 1961 onwards and referring to food supply available for human consumption, are derived from Food Balance Sheets (FAOSTAT). The gender specific infant mortality rate and the total fertility rate are drawn from UN Population Division (2003). The rainfall data was derived from Mitchell et al. (2004), version 1.1. Start and duration of wars of decolonization and civil wars were taken from the Correlates of War Project (Sarkees 2000). A threshold of 1000 battle-related deaths per year guarantees that only major wars are included. Due to averaging a dummy, the civil war variable describes the relative length of the birth period [0-1], during which a civil war took place. Thus, a value of 0 indicates that peace prevailed during the full length of the cohort's birth period, whereas a value of 1 indicates that a civil war took place in every year of the birth period. The share of urban population was taken from World Bank (1999). Finally, the GDP figures are from Maddison (2001), who provides data from 1950 onwards; missing values for Burkina Faso, Ethiopia, Guinea, and Malawi were interpolated with data from the Penn World Tables 6.1 (Heston et al. 2002).

Table 4 TSLS instrumenting economic growth

Dependent variable: $\Delta height_t$ (cm)	TSLS (1)	TSLS (2)
Endogenous explanatory variables	GDP/ c_t & GDP/ c_{t+3}	GDP/ c_{t+3}
Constant	-0.286*** (-4.65)	-0.107** (-2.25)
ΔGDP/ c_t (in %)	0.018* (1.87)	0.016*** (4.17)
ΔGDP/ c_{t+3} (in %)	0.006 (0.52)	0.011 (1.20)
Summary results first stage regressions Partial R^2 of excluded IV		
ΔGDP/ c_t (in %)	0.23**	
ΔGDP/ c_{t+3} (in %)	0.19*	0.13***
Overidentification test (p-value)	0.433	0.557
Wu-Hausman test of endogeneity (p-value)	0.780	0.896
N (countries)	62 (24)	106 (24)
R^2	0.19	0.19

Note: Instruments were investment share, black market exchange rate premium, and growth in labor force in *t* respectively *t+3*. Missing values for the black market exchange reduced the number of observations. Data on investments were drawn from the Penn World Tables 6.1, the labor force corresponds to the non-dependent population (age 15-64) and, like the black market rate, comes from World Bank (1999).

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