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Abstract

Nutrition and health are important dimensions of human well-being. Both aspects are complementary to income and deserve attention in its own right. However, there is an interrelationship between economic development and nutritional status which this study aims to investigate. We use a population's mean height as an indicator of nutritional intake net of claims due to diseases. Based on more than 200,000 women from 28 sub-Saharan African countries, we find that nutritional status was in a good state in the 1960s. However, stagnating and decreasing mean heights indicate a poor development. In fact, the entire Southwest and Southeast of the African continent went to a nutritional crisis.

In a regression analysis, we model the entire span of bodily growth and find a significant and very robust influence of economic growth on final adult height at two distinct periods: during the first years of life and puberty. We also take into account the possible endogeneity of economic development due to increased productivity, but do not find evidence of endogeneity. National food supply in form of high quality proteins and the disease environment are other important determinants of nutritional status.

1. Introduction

It is widely acknowledged that human well-being is multidimensional encompassing much more than the command over goods and services. Paying attention to soft indicators, which measure aspects of living standards complementary to income, is especially worthwhile regarding sub-Saharan Africa (SSA); contrasting the exceptionally poor economic performance, advocates of an optimistic view of African development emphasized achievements in soft indicators like education and longevity (Sender, 1999).

Nutrition and health are also essential components of the quality of life. A good measure of both of these aspects is a population's mean height. The human body thrives well in a healthy environment, in which nutrition is of sufficient quantity and high quality; deprivation and insults, in contrast, stunt bodily growth. Hence, mean heights reflect nutritional intake net of claims due to diseases and physical exertion. It is worth mentioning that genetics does not play an important role at population level. Anthropometric studies found large height differences between socioeconomic elites and poor people of the same ethnic background, more so than between African elites and a US-American reference population demonstrating the overwhelming influence of environmental conditions (Fiawoo, 1979; Habicht et al., 1974).

Mean heights are a measure of nutritional status but they also have a much broader meaning. In being very sensitive to poverty and its effects, such as hunger, low-nutrient diets, poor housing and sanitary conditions, contaminated food and water, no or limited access to medical care, child labour, etc., heights put the emphasis on the consumption of basic necessities, i.e. they are consistent with the basic needs approach of measuring welfare (Steckel, 1995). Therefore, heights are a valuable indicator of living standards deserving attention in its own right. In this paper, we

study how well Sub-Saharan African countries ranked in terms of nutritional status in the 1960s and whether nutritional and health conditions improved in the second half of the 20th century.

While both, heights and income, measure living standards, there is also a complex interrelationship between the two. On the one hand, it is often assumed that higher incomes for the poor is the most effective means for reducing undernutrition (World Bank, 1986). In fact, anthropometric studies often found a significantly positive relationship between income and height in the 20th century (Brinkman and Drukker, 1998; Steckel, 1995). On the other hand, there is an influential theoretical literature highlighting the consequences of insufficient nutrition on labour income. Leibenstein (1957) argued that nutrition determines labour productivity, which in turn influences labour income. Dasgupta (1997) used the nutrition-productivity link to explain poverty traps. At the macro level, Fogel (1994) argued that nutritional improvements increased life expectancy and that both stimulated industrialization in 19th century. In this study, we analyze the influence of income on nutritional status taking concerns of endogeneity serious. We also take into account other potential determinants like national food supply, droughts, education, civil wars, etc.

The paper is structured as follows. In the next section, we present the data and address potential limitations. In section 3 and 4, we describe the state and development of nutritional status in sub-Saharan Africa (SSA). In section 5, we clarify the time structure of the relationship between nutritional status and environmental factors. After presenting our explanatory model, we come to the regression results. The last section concludes.

2. 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).¹ 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. In this study, however, we focus on adult height, to which DHS has increasingly extended the coverage. During the second phase (DHS-II: 1988-1993) DHS started to record the body stature of mothers which became the standard for all surveys of the third phase (DHS-III: 1992–1999). In the current phase (DHS+: 1997-present), the anthropometric part 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 a headpiece, heights were recorded to the nearest millimetre. With heights of about 200,000 adult women in 28 African countries, the DHS-surveys offer an excellent anthropometric database (Table 1). Varying typically between 2,000 and 5,000, on average each survey includes 4,230 observations. Overall, the enormous number of height measurements as well as the coverage of countries represents a significant extension of the anthropometric data available on SSA (Eveleth and Tanner, 1990).

From the DHS-surveys, we calculated the women's mean height. For reducing the impact of age misreporting, 5-year age groups (20-24, 25-29, ..., 45-49) were

¹ Few DHS samples are self-weighting. Typically, subgroups constituting a small proportion of the population were oversampled to improve the precision of estimates. Other groups in turn may have been underenumerated. Sampling weights assigning each individual a weight inverse of the probability that the observation is included correct for the sampling design.

chosen as birth cohorts.² We excluded women younger than 20 years from our analysis, because many of them had not reached 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 a normal process of ageing, women begin to lose stature rapidly (Cline et al., 1989).

In 16 of the 28 countries, all women were eligible for measurement. For 12 countries, however, the anthropometric part is restricted to women who had given birth to at least one child in three respectively five years preceding the survey (later called mothers) instead of women in general were measured (Table 1). Is this selection a cause of concern? Though fertility rates are very high in SSA and, therefore, mothers represent a large share of the female population, only a subgroup of women is included (last column, Table 2). One would expect the heights of mothers to be lower; women coming from a rich household tend to have fewer children and, therefore, they have a lower probability to get sampled, so that the group of mothers consist largely of poorer (and shorter) women. In order to estimate the extent of a bias, we computed mean heights of women as well as mothers for the 16 surveys, in which DHS recorded heights of all women. In a next step, we compared the difference between mean heights of mothers with those of all women. We find that mean heights of both populations correspond closely (Table 2). Large deviations in either direction are limited to the age group 40–49 which is not surprising as only few women give birth at this age. There is only a slight structural pattern, in that the bias is greater at both ends of the age range. With a height difference of 0.14 cm, the bias is largest and

² Accurate age data is important for a birth cohort analysis, because age misreporting individuals would be assigned to wrong cohorts. The tendency to round off and thereby often preferring ages ending on 0 or 5 is more common among the lower educated strata (Ewbank, 1981). Consequently, the socioeconomic composition of cohorts is biased which also affects mean height estimates; some cohorts disproportionately comprise poorer and shorter individuals, while in others these strata are

significant in the age group 20-24. Overall, however, mothers are on average 0.05 cm shorter than all-women and deriving mean height estimates from the sub-sample of mothers introduces only a very slight selection bias. If available, all-women surveys deliver information that is more reliable and were thus preferred in our analysis. If a country is covered by two surveys and neither one is an all-women survey, we pooled the data.

DHS has not collected the height of men. How closely does the nutritional situation of the genders correlate? Can we infer the nutritional status of the male population from the sample of women? 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 favour of one gender (Moradi and Guntupalli, forthcoming). In SSA, gender discrimination in nutrition is neither very common nor severe; in many African countries, girls have a slight advantage (Klasen, 1996). However, these findings are based on child populations born after 1980 and we know little about the time before. With the World Bank Living Standard Surveys, we can check the correlation for two African countries, Cote d'Ivoire and Ghana (Figure 1). In Cote d'Ivoire, the nutritional status of males born between 1940 and 1955 improved constantly; females, in contrast, fell behind during WW2, but caught up thereafter. In the late 1950s, the secular trend slowed down in cohorts of both genders. In Ghana, gender differences are more pronounced. Though heights of males as well as females increased 1940-1955, the slope is significantly steeper for women suggesting that there were greater improvements for females during that time. Moreover, falling heights affected

missing. 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.

females about five years earlier.³ We conclude that though there is no perfect correlation, the overall pattern in the height development of the genders corresponds fairly well in SSA.

3. Nutritional status in the 1960s

For assessing the nutritional status in the cross-section, we examine mean heights of 10-year age cohorts, which were born in the 1960s. We find that African women's living standard is remarkably high in terms of nutritional status (Figure 2). Even in Madagascar and Comoros, where the shortest women live, mean height is well above 152 cm, the height that was reached by female Dutch underprivileged like orphans and factory workers born in 1849 (van Wieringen, 1972). Furthermore, most African women were taller than the approximately 155 cm of Irish women born in pre-famine 1830 (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 in Africa also compares 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, 2005; Moradi and Guntupalli, forthcoming). We therefore conclude that African women were remarkably tall and that the nutritional status in the 1960s can be considered some 20-100 years behind OECD countries.

³ When comparing the experience of neighbouring Cote d'Ivoire with that of 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 both countries.

Using income as a measure of living standards one would come to a different conclusion (Figure 2). More than half of the countries in our sample had a GDP/c lower than the one realized by the US in 1820 and 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, rank 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 a couple of explanations why anthropometric outcomes in Africa deviate from the height-income relationship usually found.⁴ In the semi-arid and arid regions of Africa, livestock farming is a widespread activity providing an important source of high-quality proteins. Such proteins are of high nutritional value favouring body growth in particular. Moradi and Baten (2005) found cattle density to be a significant predictor of height differences within African countries. The like is evident at country level; the five countries ranking highest in terms of nutritional status are Sahel countries, in which cattle holdings are high. The specialization in animal husbandry, however, is not associated with income. The limited influence of GDP/ c on nutritional status can also be attributed to 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, a large amount of wealth was going to foreigners and income was very unevenly distributed. In fact, a majority of the population in both countries lived in pronounced poverty and national income failed to translate into corresponding nutrition and health levels.

4. 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 of mean height indicates a severe crisis. In the 20th century, even stagnating heights could be considered as an indication of nutritional problems since we would expect that the spread of knowledge on hygiene and medical care normally results in lower energy expenditures and in more energy left for growth (Baten, 2003; Komlos, 1999). Thus, a stagnation of mean height may only occur, if food consumption of a sufficiently large number of individuals decreases either quantitatively or qualitatively.

In fact, there is evidence for a considerable transfer of medical knowledge to SSA in the period 1960-1980. Vaccination programmes increasingly provided protection against whooping cough, small pox, tuberculosis and other diseases (see WHO, 1983 and earlier issues of the World Health Statistics Annual). These efforts had an impact on the output side as indicated by steadily declining infant and child mortality rates and crude death rates (Hill, 1992; UN Population Division, 2003). However, progress did not occur continuously. In the 1950s, for example, the WHO initiated a global malaria eradication campaign. Initially the programme did well (WHO, 1966), but it failed eventually; malaria vectors and the parasite became increasingly resistant to insecticides and malaria drugs like chloroquin, respectively. Large-scale benefits to health were realized in the 1980s, when oral rehydration products for treating children with diarrhoea became available and the pace of immunization coverage was accelerating (UNICEF, 1996). Similarly, the share of population with access to safe water varies without a clear tendency of improvement

⁴ In a global sample of countries, the nutritional status of (West) African women also appears better than per capita income would suggest.

(World Bank, 1999). Consequently, decreasing or stagnating heights may reflect problems in both, nutrition and health.

The development of heights stands in striking contrast to the good state in the cross-section. For a number of countries either a downward or no clear trend can be observed (Figure 3, Figure 4). Heights decreased at about one and a half centimetre in Chad, Guinea, Namibia, and Zimbabwe. In Mozambique and Niger, the younger cohorts attained a stature one centimetre smaller than the generation before. 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 5, Figure 6). Improvements mainly came to a halt in the birth cohorts of 1960s with mean heights subsequently moving down to the level of the 1950 birth cohorts. Only in Burkina Faso, CAR, Nigeria, and Togo a height advantage over the past still existed. There are only a few sub-Saharan African countries showing a clear upward trend in nutritional status (Figure 7). Kenyan women born in 1975 became two centimetres taller than their counterparts born two decades before. In Cote d'Ivoire, the upward trend is weak although very continuously. Tanzania and Senegal achieved impressive gains in height of one centimetre 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.

We conclude that although many African countries made steps forward in the second half of the 20th century, eventually almost the entire Southwest and Southeast of the African continent went to a nutritional or health crisis. With the poor development, the sub-Saharan region appears as an important exception from the

worldwide trend of upward-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 almost naturally.

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 the recession by about one decade. Before going into the relationship between nutritional status and economic growth, we clarify the modelling of the time structure of the cohorts' mean adult height on the one hand and environmental conditions on the other hand.

5. Modelling the time structure

We examine the changes in nutritional status from cohort to cohort applying a birth cohort analysis. The dependent variable is the difference in mean height of adjacent birth cohorts

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

Where y is mean height and $t=1, 2, \dots, 6$ denotes the age groups 45-49, 40-44, ..., 20-24 for a given country.⁵

⁵ Note that t can comprise different birth periods depending upon when the DHS-surveys took place. For instance, the age group 35-39 in the Ghana 2003 survey was born 1963-68, while the same age group in the Madagascar 1997 survey implies the birth years 1957-62.

For a regression analysis, it is important that the explanatory variables describe the changes in conditions, under which the cohorts grew up. A straightforward approach is to take the average from annual values covering the complete span of the cohort's birth years. Then, analogous to (1), we can take first order differences or growth rates:

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

It is a common assumption that environmental conditions during the first years of life determine final adult height while conditions at later ages are negligible (Baten, 2000; Martorell and Habicht, 1986). The equation that reflects this assumption is

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

However, adult height is a result of increases in stature from birth to maturity and a lower adult height might have been caused by insults during childhood or adolescence. Modelling the entire growth span is preferable. Brinkman et al. (1988) assumed that the influence of environmental circumstances at a given age is proportional to the share of growth typically accomplished at that age. They proposed to use aggregated variables, where the annual values are weighted according to typical Yearly Age and Sex Specific Increases in Stature (YASSIS). The problem with this approach, however, is that it is uncertain whether a determinant indeed influences bodily growth at all ages. Weighting the determinants 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 have the highest explanatory power on final height, while the weighting scheme reduces the explanatory power.

Our approach is based on the following consideration. If a changing environment affects bodily growth at a particular age so that it influences final adult height, a regression should be able to reveal this systematic impact (Figure 8). We simply have to include those environmental changes after birth into the regression. Technically, the explanatory variables are shifted temporally ahead.⁶ The general form of the regression equation is

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

with K explanatory variables, which cover the cohorts' birth period only, and Z explanatory variables, for which we assume that they influence 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 birth period respectively. Precise insights into the temporal pattern are not feasible, as the cohorts cover 5-year age groups; uneven and superjacent influences within the cohorts become smoothed and are expressed as an average.

6. Determinants of the temporal variation in heights

In this section, we discuss factors, which might explain the poor development in nutritional status. An important underlying determinant is economic growth. The World Bank (1986) propagated that income is the binding constraint for an adequate nutritional intake. There are many impoverished households in SSA spending a

⁶ It is also possible to shift the dependent variable temporally ahead and keeping the time structure of the explanatory variables unchanged, e.g. shifting the cohort's mean height by one period would give

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. The African climate, for instance, is often blamed for the harsh disease environment though investments in public health care can help to prevent or cure the diseases. It is due to poverty that medical personnel, clinics, drugs and equipment, access to clean water and sanitation are lacking. Overall, we would expect a positive impact of economic growth, especially since idiosyncrasies like the specialization in livestock farming or climate related exposure to diseases do hardly play a role for the temporal variation in height.

The income-height nexus can also be seen from a different perspective. In African economies, work often relies on physical strength and endurance and, therefore, on nutrition and health of the workers. Labour productivity provides the link for a causality running from heights to income (Leibenstein, 1957; Strauss and Thomas, 1998). In our analysis, endogeneity can arise from two sources. Firstly, nutrition in the cohorts' early years of life can positively correlate with nutrition and health of the adult labour force (Fogel, 1994). If a better nourished and healthier labour force is more productive, output increases. In this case, economic growth is endogenous and the OLS coefficient would overestimate the actual influence of GDP/c on nutritional status. Secondly, similar arguments apply, when the cohorts themselves enter the labour force. Their own nutritional and health status gives rise to the productivity link, even more so if nutritional status of women correlates with men of the same age group.

We follow an instrumental variable approach to address the endogeneity of GDP/c. The empirical growth literature provides several candidates of valid IVs:

us the impact of the environment during late childhood.

From a neoclassical production function, it follows that output is a function of capital and labour, so that the investment rate and growth in the labour 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 time, when the cohorts themselves enter the labour force, may occur in $t+3$ at the earliest. We keep our set of IVs but adjust the time structure accordingly.

GDP/ c is not the only potential determinant of nutrition and health. In order to estimate a comprehensive regression model, we add several other variables to our explanatory model. National food availability is one parameter for adequate dietary intakes. The kind of food differs between the countries, e.g. in Zambia the staple food is maize, and it is rice in Madagascar and sorghum and millet in Chad. With expressing the food supply by the nutritional value, in calories or proteins, the overall food situation becomes comparable. We include protein supply stressing the quality aspect to a higher degree.⁷ Especially high quality food like meat, fish, eggs, and milk contain large amounts of proteins. Milk is often fed to infants. Moreover, protein-rich food has further important nutrients like calcium, iron and phosphorus, all of which are important inputs for muscle and bone formation and therefore favour bodily growth in particular.

A population's nutritional status is not only determined by food availability but also by nutritional needs. In particular, diseases inhibit the absorption of nutrients in food and put a strain on children's energy. Unfortunately, reliable data on health inputs are in scarce supply. Following Schneider (1996) und Weir (1993) we use the

⁷ 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).

infant mortality rate as a proxy for the epidemiological environment. A drawback of this proxy variable is that it might be determined simultaneously with nutritional status.

Increases in family income need not necessarily translate into more resources available to children. It is important to consider changes in intrahousehold allocation, which we 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 nutrition and health of their children. Therefore, an decreasing fertility rate should be associated with a rise in mean height (Weir, 1993). A variable, which let us directly observe investments into children, is the education the cohorts attained. Education also serves as a proxy for the provision of public goods other than schooling, so that we would expect a positive impact on nutritional status.

In SSA, the great majority of people is living from agriculture. Rain fed cropping systems are predominant which makes rainfall an essential input in agriculture (Benson and Clay, 2000). Especially subsistence farmers, small tenants and landholders, and pastoralists rely on rainfalls. 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. Factors shielding the cities range from a better accessibility to food policies biased in favour of urban areas. Consequently, droughts have distributional effects that are not accounted by economic growth.

Extreme droughts triggering devastating famines occurred in 1968-1973 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 had more than two consecutive drought years. In addition to short-term shocks, the Sahel countries experienced a systematic decrease in rainfall; precipitation in the period 1961-90 was 10-20% lower than the three decades before (Hulme, 1992). Overall, we expect that droughts as well as less severe deviations from normal rains affect nutritional status negatively.⁸

Civil wars are another all too frequent tragedy in SSA with detrimental effects on nutrition and health. Farmers are prevented from timely sowing and harvesting or, fleeing the war, they completely abandon their fields; blocked roads and partitioning disrupt the allocation of goods and foods. The epidemiological environment is also likely to deteriorate. The destruction of health facilities and cuts in their capacities let break down basic health care delivery like vaccinations or prenatal care; other services important for hygiene like water pumps can often not be maintained. 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. Thus, civil wars affect the public health system in a time of increased need. The 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.

We finally include urbanization. Indicating a transition from a traditional to a modern and industrialised society, the process of urbanisation is associated with an increased complexity in the value added chain (Tiffen, 2003). Therefore, urbanization

⁸ It would be ideal to follow the conceptualisation 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

can complement GDP/ c, e.g. if primary commodity booms inflate national income without a broad diffusion of benefits like in Gabon, Namibia, Nigeria, or Zambia. Moreover, there is a large urban-rural divide in living standards. Urban areas provide better housing, health services, employment opportunities, access to public goods like water and sanitation services, and so on. On average, city dwellers enjoy a height advantage (Loaiza, 1997). Urbanization could simply mean an increasing share of population, which benefits from the amenities.

7. Results

The regression analysis reveals very interesting insights (Table 3). In contrast to the lack of correlation between GDP/ c and mean height in the cross section, we find that economic growth does affect the development of mean heights significantly positively. The time structure of the influence is very interesting. Besides a positive effect of economic growth in early years of life (in t), we additionally find a positive effect in $t+3$, which roughly corresponds to the time of puberty (OLS (2), Table 3). It is widely acknowledged that bodily growth is very sensitive to conditions during early years of life. After weaning, toddlers have quantitatively and qualitatively high energy needs and they are highly vulnerable to infections due to unhygienic conditions or contaminated food (Martorell and Habicht, 1986). Since a large share of total height is acquired in the first three years of life, growth retardation in early years of life translates into a permanent loss of stature, especially when conditions do not improve dramatically so that catch-up growth is negligible. It is also known that undernutrition shapes bodily growth at puberty delaying the adolescent growth spurt, slowing down

important. Though the concept of agricultural droughts does better describe conditions eventually

bodily growth and lengthen the growth span (Bogin, 1988). Some scholars believe that the prolonged growth phase balances out the lower growth velocity (Kulin et al., 1982). However, our results suggest that conditions at puberty did contribute to the deficit in final adult height of African women.

Acknowledging the effect at puberty is important to avoid misinterpretations. In many African countries, the development of mean height followed an inverted U with the trend reversal often occurring in cohorts born in the mid-1960s (Figure 5, Figure 6). From these trends, we cannot infer that environmental conditions started to deteriorate in the 1960s. The significant coefficient of economic growth in $t+3$ demonstrates that instead, the crisis of the late 1970s and 1980s and its influence on body growth at puberty must be partly considered responsible for the falling mean adult heights of the mid-1960s birth cohorts. It is noteworthy, that the severe economic crisis in the 1980s may have given raise to the influence at puberty. When we restrict the sample on cohorts born before 1965, we find the impact in $t+3$ reduced (though the effect in $t+2$ becomes stronger).

The impact of economic growth is substantial. Growth in $\Delta \text{GDP}/c$ between the 5-year age cohorts averages 4% and varies with a standard deviation of 12.4 between -27% and 36% (OLS (1) and (2), Table 3).⁹ Hence, a difference in economic growth in the order of one standard deviation would change mean adult height of the cohort, which is in their infancy (the impact in t), as well as the cohort, which is in the age of puberty (the impact in $t+3$), by 0.1 cm.

In the first two regressions, unavailable data on protein supply and urbanization restrict our analysis to cohorts born 1963-84. When excluding these variables, the

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

⁹ The figures refer to $\Delta \text{GDP}/c_t$, $\Delta \text{GDP}/c_{t+3}$, which covers the 1980s and even 1990s, averages -4% and varies with a standard deviation of 11.8 between -46% and 23%.

sample increases in size and covers cohorts born in the 1950s (OLS (3) and (4), Table 3). The impact of economic growth is increasing in significance. Moreover, we can find the positive influence in $t+3$ crossed over to $t+2$. We also ran a country fixed effects regression in order to control for country-specific, deterministic time trends in height (FE (5), Table 3). Under this specification, the estimated impact of income almost doubles. Though fixed effects are not significant at conventional levels (p-value: 0.13), they indicate that the experience of at least some countries differs. This is the case for Niger and CAR, where the development of mean height was consistently better than expected. In Namibia and Zimbabwe, in contrast, mean heights were *ceteris-paribus* decreasing by half a centimetre per 5-year-cohort. One may wonder whether the social and economic discrimination of the black majority in both countries might be the reason that nutrition and health deteriorated despite of substantial economic growth (Figure 3).¹⁰

The link between nutrition and labour productivity makes income growth possibly endogenous. In this case, OLS estimates would be upwardly biased. We therefore instrument for economic growth in both, t and $t+3$. The size of the TSLS coefficient for income growth in t ranges between the OLS and FE estimator (TSLS (1), Table 4). Moreover, the influence is significantly positive. The effect in $t+3$ is also positive, but slightly lower and insignificant. The reason for this result is that, surprisingly, our IVs are less powerful for economic growth in $t+3$, i.e. 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

¹⁰ Note, that the slope coefficient of economic growth is assumed to be equal for all countries. When testing for a structural break in the height-economic growth relationship for those countries, the coefficients of economic development turned out to be very similar indicating that the concern is indeed country-specific differences in the development of mean height.

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 very similar to the OLS one. This confirms the Wu-Hausman test indicating that we cannot reject the null of exogeneity of economic growth.

There are factors, which can dwarf the case of endogeneity at the macro level. Nutrition of labourers and children need not correlate very strongly. Given the nutrition-productivity link, we would expect a utility maximising household to treat its members unequally (Behrman, 1997; Dasgupta, 1997). In fact, the consumption of household members, whose labour contributes to the household's income, might be rather inelastic. Furthermore, one may doubt, whether total value added, to which a single 5-year age group of juvenile age contributes (in $t+3$), is significant enough that increased labour productivity caused by a taller stature measurably influences economic growth.

The importance of economic development is overwhelming.¹¹ When controlling for other determinants only the proxy variables of nutrition and health are significant predictors of height. Food supply in form of proteins influences nutritional status significantly positively, which is in line with studies of child undernutrition (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 is fitting the overall height pattern particularly well. In the late 1960s, growth rates in per capita food availability tended to decrease and African countries became more homogeneous in this respect. Infant mortality rate also

¹¹ One can argue that economic growth is an underlying determinant, which influences immediate determinants like health environment and food supply. Given this causal framework, the determinants should be treated rather separately. Unsurprisingly, including them into a single explanatory model reduces the effect of economic growth in t .

has the expected negative sign, so that declining infant mortality rates were associated with increasing mean heights of African women. Taking the infant mortality rate as health indicator, progress in health only slightly slowed down in the 1970s, and therefore, health cannot explain the overall trend in nutritional status.

The other variables do not add much explanatory power (OLS (2) and OLS (4), Table 3). The education the cohorts attained is insignificant. Micro studies of undernutrition, in contrast, regularly found a positive effect, notably of the mothers' education. Her education increases the likelihood of good childcare practices. Accurately modelling this effect at the macro level is unfeasible. However, we would also argue that education serves as an indicator of social status, which let micro studies overestimate the true influence of education. The civil war variable is also insignificant. Though without doubt, ordinary people always suffer in conflicts, the effects appear to be sufficiently accounted for by economic growth. On average, civil wars are associated with a 10% fall in GDP/ c suggesting that nutritional status decreases in the course of civil wars. Finally, fertility and urbanization cannot explain the development of mean heights in SSA and though rainfall has the expected positive impact (OLS (3), Table 3), it is not very robust.

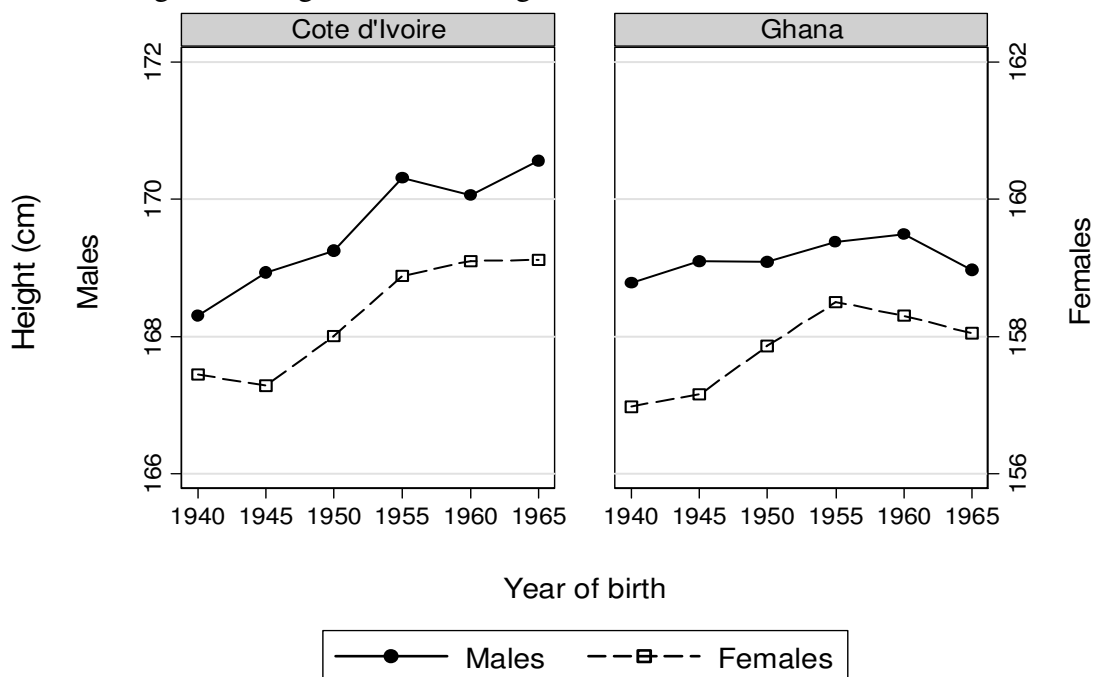
8. Summary

Advocates of an optimistic view of African development emphasized achievements in soft indicators like education, child mortality, and life expectancy, which stand in some contrast to the poor economic performance of SSA. In this paper, we focused on another dimension of the quality of life. We studied mean heights, which reflect nutrition and health the populations have faced during bodily growth.

Using heights of more than 200,000 women from 28 sub-Saharan African countries, we found that nutritional status was in a good state in the 1960s. However, the development of heights indicates a deterioration of nutritional status. In a number of countries, mean heights stagnated or decreased and even though several African countries made some improvements, eventually the entire Southwest and Southeast of the African continent went to a nutritional crisis. Overall, sub-Saharan Africa represents an important exception to the trend of upward-sloping heights found in almost all other regions of the world in the 20th century.

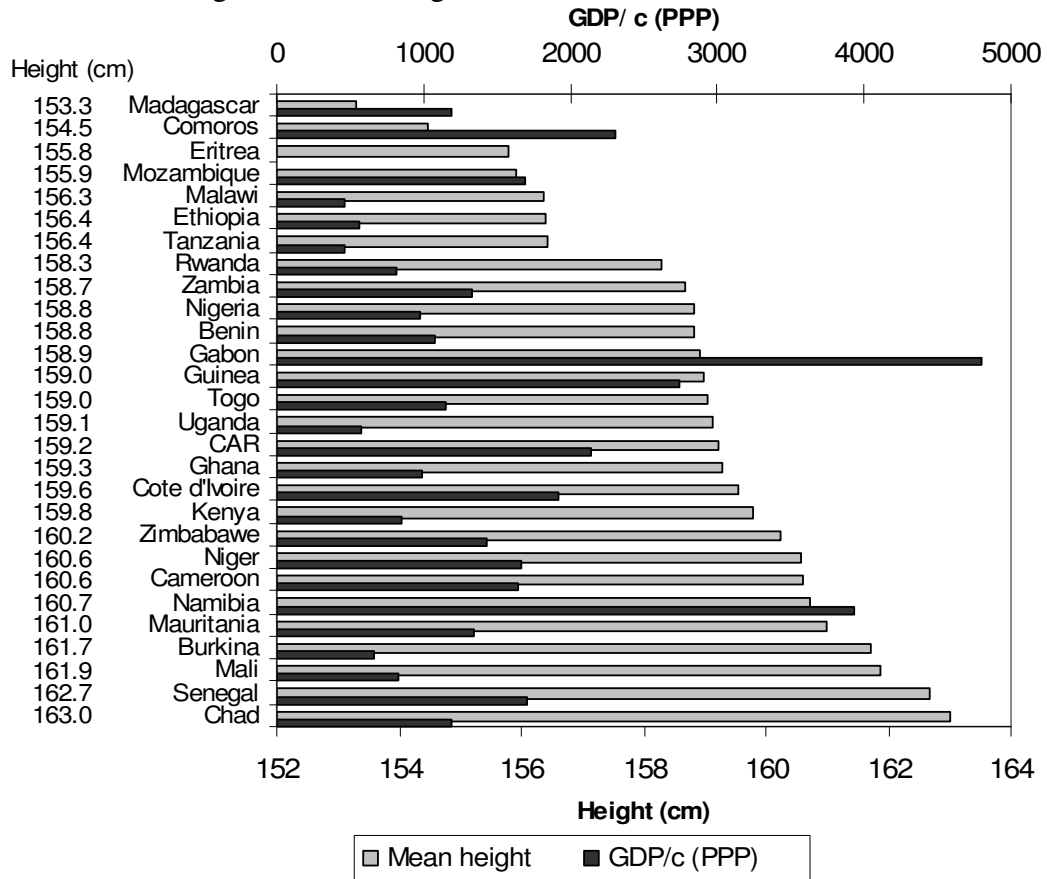
In a regression analysis, we tested the explanatory power of the economic development and several other determinants on temporal height variations. The results indicate that economic growth was a powerful factor influencing the physical growth process at two distinct periods: during infancy as well as adolescence. Income shocks at both times had a lasting effect on final adult height. The effect at puberty suggests that the severe economic crisis of the late 1970s and 1980s played a role for the trend reversal occurring in cohorts born in the mid-1960s. We also took into account the endogeneity of income, plausible via the nutrition-productivity link, but did not find evidence of endogeneity. The results have also implications for one of today's most pressing problems. In the fight against undernutrition, a promising weapon is bringing African countries back to the path of economic growth they left in the 1970s.

Figure 1: Height trends of the genders in Cote d'Ivoire and Ghana



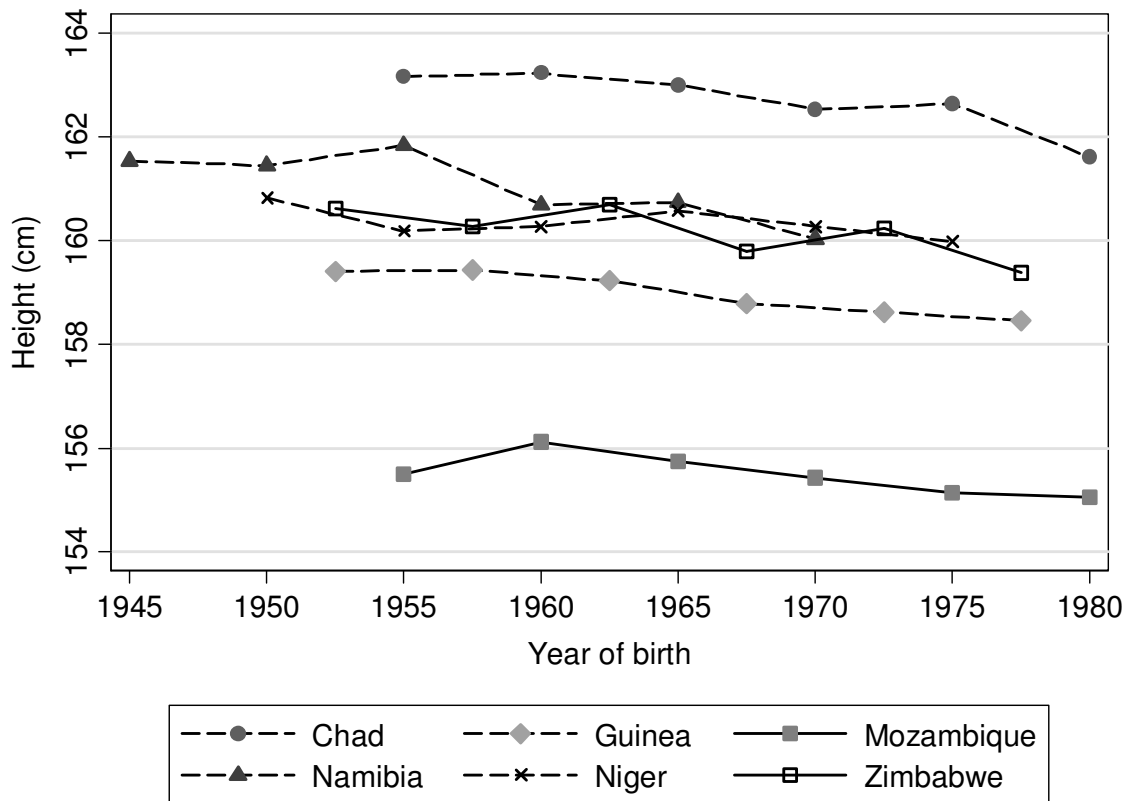
Note: The data is drawn from the Living Standard Measurement Study surveys GLSS 1988/89 and CILSS 1985/86/87/88 (World Bank). About 40% of the individuals in the CILSS and 60% in the GLSS survey were remeasured in a second round. Inconsistencies between the first and second rounds (sex, age > 5 years, 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 2: Mean height of women and GDP/c, 1960s



Note: GDP/c figures are from Penn World Tables 6.1 (Heston et al., 2002). US GDP/c (PPP) in 1820, 1870, and 1913 was approximately 1360, 2650, and 5740 (Maddison, 2001).

Figure 3: 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. All-women surveys, which are representative of the total female population, are in solid lines.

Figure 4: Stagnating mean heights

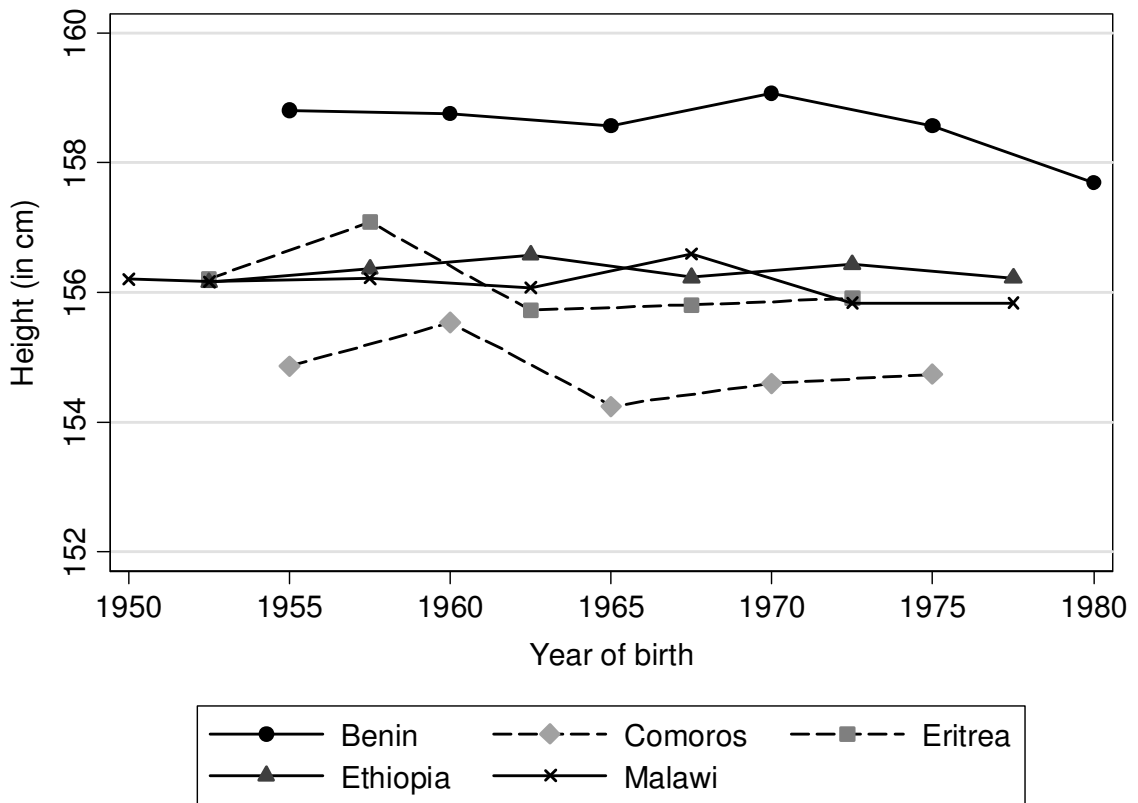


Figure 5: Height trends following an inverted U (1)

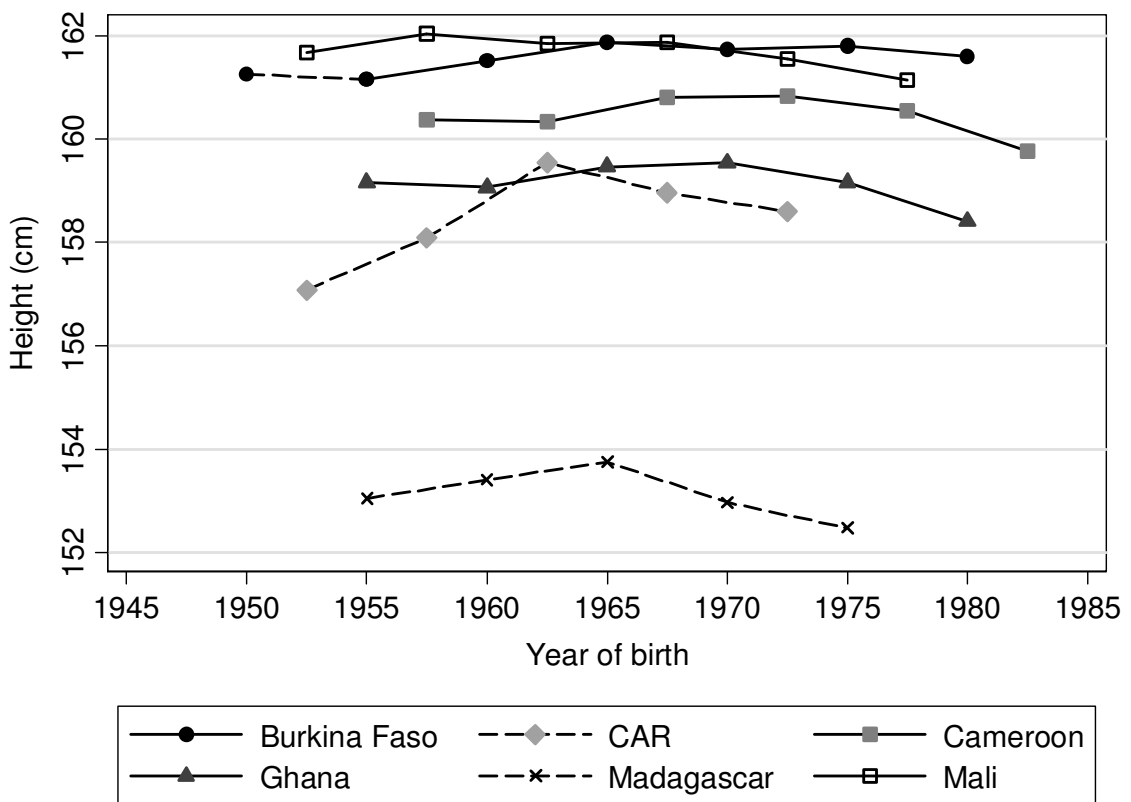


Figure 6: Height trends following an inverted U (2)

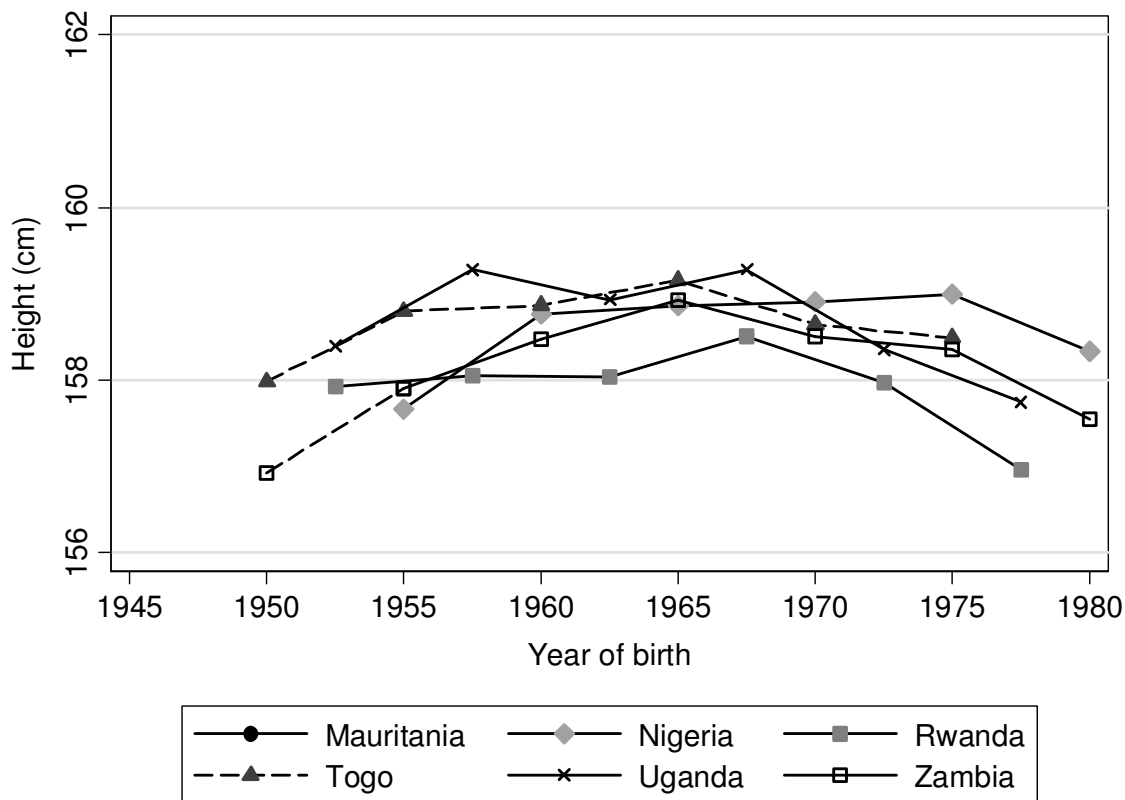


Figure 7: Increasing mean heights

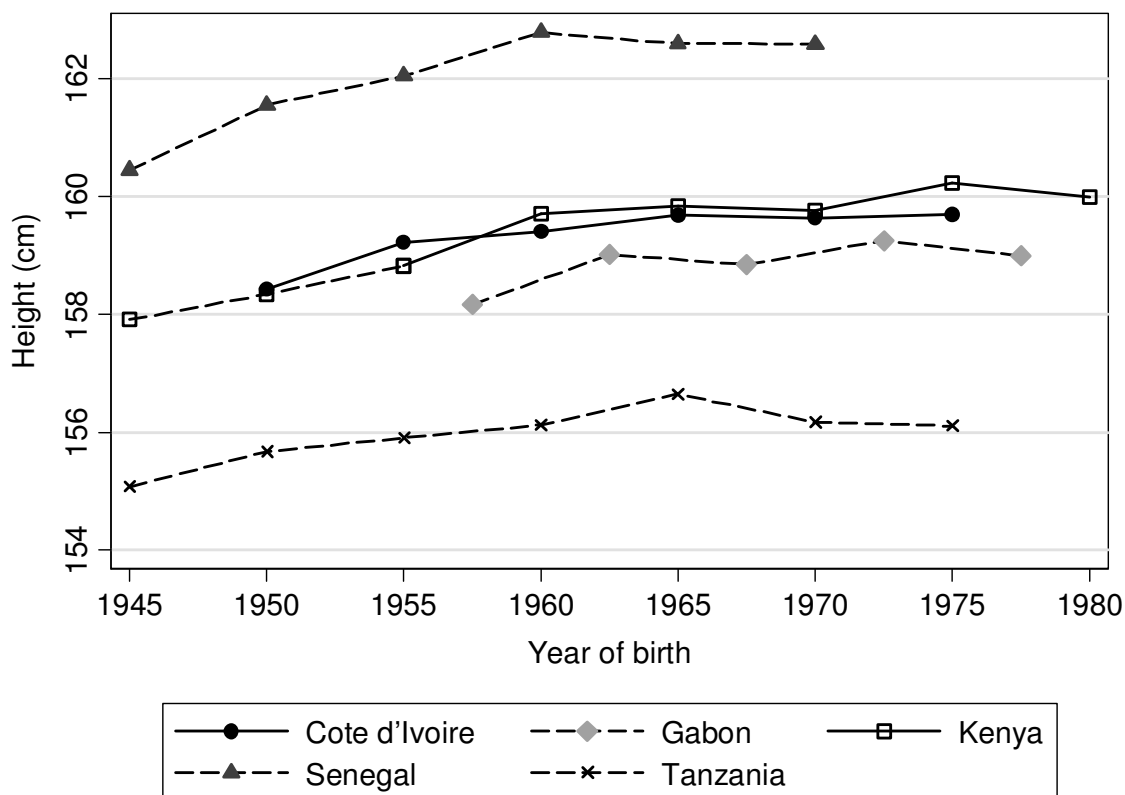


Figure 8 Modelling the entire growth period with leaded explanatory variables

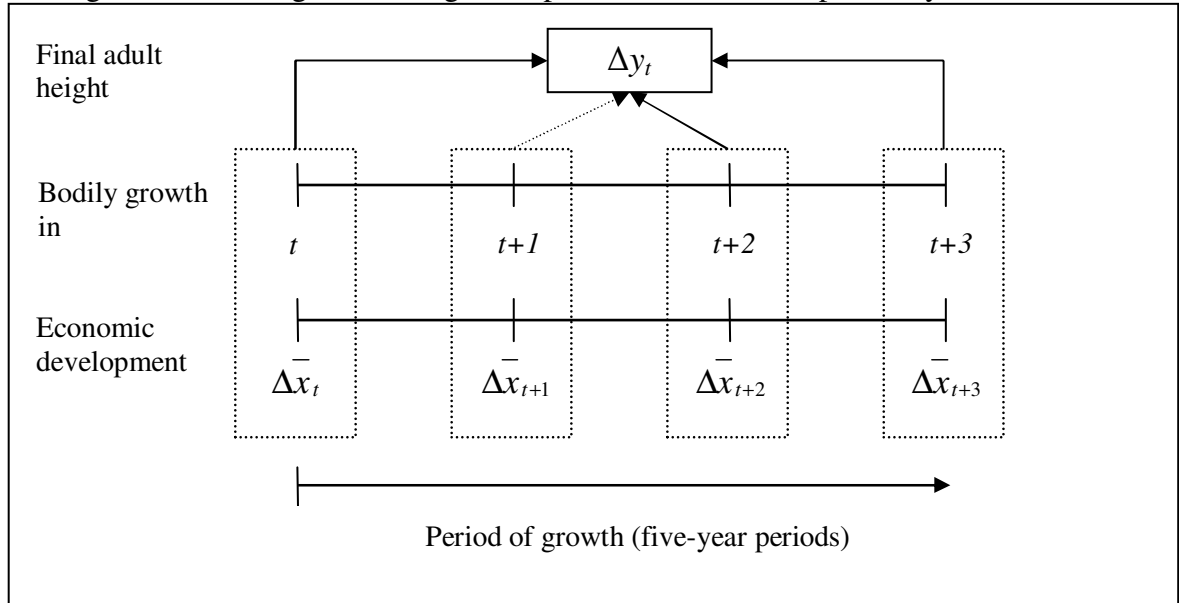


Table 1 Anthropometric data in the DHS-surveys

Country	Date of survey	Coverage (M=Mothers, AW=all women)	Number of women (Age group 20-49)
Benin	1996 & 2001	M & AW	2400 & 4957
Burkina Faso	1992/93 & 1998/99 & 2003	M & M & AW	3459 & 3569 & 9547
Cameroon	1998 & 2004	M & AW	1609 & 3890
CAR	1994/95	M	2050
Chad	1996/97 & 2004	M & M	3940 & 3193
Comoros	1996	M	835
Cote d'Ivoire	1994 & 1998/99	M & AW	3017 & 2221
Eritrea	1995	M	1836
Ethiopia	2000	AW	11656
Gabon	2000	M	2359
Ghana	1993 & 1998 & 2003	M & M & AW	1785 & 2216 & 4374
Guinea	1999	M	3401
Kenya	1993 & 1998 & 2003	M & M & AW	3425 & 3378 & 6010
Madagascar	1997	M	2580
Malawi	1992 & 2000	M & AW	2495 & 10152
Mali	1995/96 & 2001	M & AW	4438 & 9833
Mauritania	2000	AW	5910
Mozambique	1997 & 2003	M & AW	3158 & 9253
Namibia	1992	M	2381
Niger	1992 & 1998	M & M	3569 & 3466
Nigeria	2004	AW	5737
Rwanda	2000	AW	7544
Senegal	1992/93	M	3178
Tanzania	1992 & 1996	M & M	4711 & 3959
Togo	1998	M	3470
Uganda	1995 & 2000/01	M & AW	3401 & 5118
Zambia	1992 & 1996 & 2001/02	M & M & AW	3386 & 4084 & 5762
Zimbabwe	1994 & 1999	M & AW	1948 & 4219
Total: 28 countries	1992 - 2004	31 M & 16 AW	198879

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

Table 2 Height difference between women and mothers

Age group	Height difference (in cm) women - mothers		Share of mothers (%)
	Mean	Standard deviation	
45-49	0.074	0.587	22.1
40-44	-0.064	0.450	45.3
35-39	0.012	0.283	64.5
30-34	0.069	0.161	75.2
25-29	0.052	0.159	78.4
20-24	0.144	0.216	66.5
Total (N=96)	0.048 (1.359)	0.344	58.7

Note: Mothers are defined as women who had given at least one birth in the 59 months prior to the date of interview. Based on Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mali, Mauritania, Mozambique, Rwanda, Uganda, Zambia, and Zimbabwe (N=16 per age group); t-value of the null hypothesis that the height of women and mothers are equal in parentheses.

Table 3: OLS-Determinants of temporal variation in heights

Dependent variable: Δ height (cm)	OLS (1)	OLS (2)	OLS (3)	OLS (4)	FE (5)
Age groups included (Period: ...-1979/84)	20-39 (1963/69)	20-39 (1963/69)	20-44 (1953/59)	20-44 (1953/59)	20-44 (1953/59)
Constant	-0.433*** (-2.77)	-0.441*** (-3.61)	-0.222 (-1.42)	-0.099** (-2.10)	-0.119** (-2.52)
Δ Protein supply/ c (in %)	0.017** (2.26)	0.017** (2.59)	-		
Δ IMR, females	-0.020 (-1.57)	-0.021* (-1.90)	-0.014 (-1.06)		
Δ Cohort's education (in years)	0.001 (0.01)		0.001 (0.01)		
Δ Rainfall (in %)	-0.003 (-0.46)		0.010* (1.98)		
Civil war	0.061 (0.34)		-0.180 (-0.95)		
Δ Total fertility rate	0.228 (0.70)		0.513 (1.64)		
Δ Share of urban population	-0.011 (-0.39)		-		
Δ GDP/ c _t (in %)	0.010** (2.38)	0.009** (2.48)	0.010** (2.25)	0.013*** (3.35)	0.020*** (4.41)
Δ GDP/ c _{t+1} (in %)	-0.003 (-0.69)		-0.003 (-0.69)		
Δ GDP/ c _{t+2} (in %)	0.001 (0.40)		0.009** (2.49)	0.009*** (2.69)	0.014*** (4.13)
Δ GDP/ c _{t+3} (in %)	0.011** (2.44)	0.011*** (2.98)	0.009** (2.36)	0.010*** (2.74)	0.017*** (4.43)
Country fixed effects (p-value)					0.126
N (countries)	72 (27)	72 (27)	117 (27)	117 (27)	117 (27)
R ² -adj.	0.17	0.24	0.19	0.18	0.20

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 a couple of sources. The figures on protein supply, available from 1961 onwards and referring to food supply available for human consumption, are derived from the FAO 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 stems from Mitchell et al. (2004), version 1.1, and are calculated for the countries' territory. From the Correlates of War Project, we derived the start and duration of wars of decolonization as well as civil wars (Sarkees, 2000). A threshold of 1000 battle related deaths per year guarantees that we include major wars, which presumably affected a large part of the population. Due to averaging a dummy, the civil war variable in Table 3 describes the relative length of the birth period [0-1], during which a civil war took place. Thus, a value of zero indicates that peace prevailed during the full length of the cohort's birth period, while a value of one 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: Δheight_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)
$\Delta \text{GDP}/ c_t$ (in %)	0.018* (1.87)	0.016*** (4.17)
$\Delta \text{GDP}/ c_{t+3}$ (in %)	0.006 (0.52)	0.011 (1.20)
Summary results first stage regressions		
Partial R^2 of excluded IV		
$\Delta \text{GDP}/ c_t$ (in %)	0.23**	
$\Delta \text{GDP}/ c_{t+3}$ (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 labour 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 labour 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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