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Climate, height and economic development in sub-Saharan Africa

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Environmental conditions leave an imprint in the human body. The physical development of children is enhanced by a healthy environment, including high-quality nutrition in sufficient quantities. Deprivation, in contrast, stunts body growth. As a consequence, children suffering from chronic malnutrition fall short of their genetic growth potential and, on average, become shorter adults. This will reflect in a population's mean height. Insofar as nutrition and health are correlated with income, heights should be correlated with income. Numerous articles found richer individuals on average taller than the poor. One would expect to find the same relationship at country level.

The puzzlingly tall stature of African populations in the cross-section

African populations are, on average, much taller than their low income would suggest. This is best illustrated when plotting mean height against GDP/c: African populations (round black dots) are clustered above the line of best fit (Fig.1). There is also no correlation between GDP/c and mean height *within* sub-Saharan Africa (Deaton, 2007; Moradi, 2010a).

If not income, what can explain mean height levels in SSA? Interesting clues are offered by older studies, which related heights to climate. Roberts (1953) found African heights to increase with temperature and to fall with relative humidity. When repeating the exercise with a bigger sample of administrative regions, we find the results largely confirmed (column 1, Tab. 1). We test two more climate variables a) precipitation and b) diurnal temperature range. While the former is not significant, the latter turns out to be a better predictor of height than humidity (columns 2 and 3, Tab. 1). Results of a country fixed effects regression indicate that the correlations also hold across regions within countries (column 4, Tab.1).

Roberts (1953) linked the correlations to evolutionary adaption: Africans have an optimal body shape for the tropical climate because tall and slim bodies with long limbs assist in the loss of body heat. We confirmed the impact of climate, but we do not agree with Roberts' interpretation in respect to body height and weight. Roberts ignored the proximate causes of height.

We argue that climate influences heights through nutrition and diseases. One can see this in the spatial pattern of mean heights plotted in Figure 2. Firstly, tall women can be found in tsetse fly free areas – the Sahel region, areas around Lake Victoria, Namibia, Zimbabwe and southern parts of Zambia. The tsetse fly is a vector transmitting trypanosomes, which are deadly for livestock. They especially limit cattle herding, which provides an important source of high quality nutrients (proteins, minerals from milk, blood, meat) used in body growth (Moradi & Baten, 2005). The distribution of the tsetse fly is related to temperature, rainfall and vegetation. Secondly, women in forest regions tend to be shorter (Central Africa, in West Africa in between the coast and the Sahel zone). The climatic conditions in the tropics facilitate the spread and development of bacteria and parasites, not necessarily a high mean temperature but a *stable* temperature, that is a small diurnal temperature range, consistent with the positive regression coefficient found in Table 1.

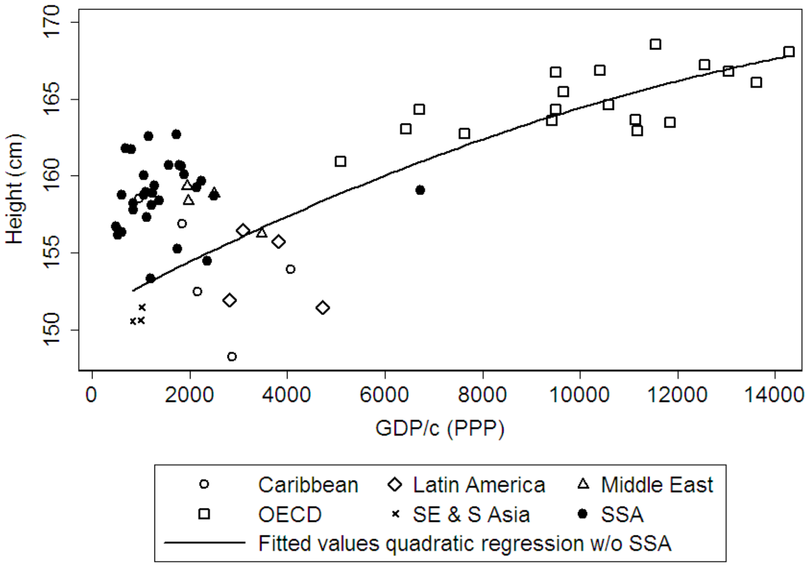

Fig. 1 - Height-income relationship in a global sample (women, 25-34 years). GDP/c (PPP, international $) figures are from the Penn World Tables 6.1 and averaged over the cohorts' 10-year birth period. N(countries)=63. Source: Moradi (2010a).

The strong correlation between climate and height is interesting. It helps to understand the lack of correlation between GDP/c and height. There is little reason to expect temperature or temperature range to be correlated with national income - in fact they are not (column 5, Tab. 1). There is also no correlation between GDP/c and national protein supply (as well as livestock) in Africa in the 1960s. In the last 50 years, however, there is a trend towards a stronger correlation between income and protein supply.

Body growth at puberty - the missing link?

While climate is an important explanation for the missing correlation between income and height, it is unsatisfactory when the tall stature of Africans is concerned. The climate is a major cause of the epidemiological environment in Africa, which is worse than in other regions of the world as reflected in a number of measures such as infant mortality rates, prevalence of diarrhoea and malaria. Clearly, one would expect the adverse epidemiological environment to take its toll and lead to short heights. Why doesn't it?

Actually, it does. In sub-Saharan African countries the prevalence of stunting (low height-for-age) is high among children younger than 5 years. Moreover, heights of children are mostly in line with global patterns of nutrition and health conditions. Thus, the puzzle of tall Africans is primarily one of adult height emerging some time after age 5 years (Moradi, 2010b). Anthropometricians typically assume that the first years of life are most crucial for attained adult height and downplay the impact that growth at ages 5-20 years can have. However, there is not a single longitudinal study substantiating this result for Africa.

We can only speculate why sub-Saharan Africa may be different. Puberty offers a window of opportunity. African adolescents may be less vulnerable to the disease environment. Moreover, adolescents may find greater consideration in the intra-household allocation of resources, especially when their contribution to household income increases as well.

Tab. 1 - Climate and mean height of women in administrative regions in SSA, ca. 1960-19701.

	MEAN HEIGHT (IN MM) (ADMINISTRATIVE REGIONS)				GDP/C (PPP) (COUNTRY)
	(1)	(2)	(3)	(4)	(5)
Annual temperature (ºC)	2.012*** (0.605)	3.276*** (0.879)	3.097*** (0.670)	1.276 (0.830)	-40.66 (60.46)
Diurnal temperature range		5.436*** (1.773)	4.779*** (1.004)	2.204*** (0.803)	115.07 (217.04)
Relative humidity (%)	-0.694*** (0.168)	0.098 (0.29)			2.155 (-26.51)
Precipitation (mm)		0.015 (0.063)			6.15 (5.63)
Country Fixed Effects	NO	NO	NO	YES	
R-sq.	0.35	0.41	0.41	0.73	0.04
N(countries/regions)	33/271	33/271	33/271	33/271	38

[1] ***Heights were derived from Demographic and Health Surveys (DHS) and averaged by administrative regions, shown in Figure 2. Birth cohorts were 10 year-age-cohorts centred in the 1960-70 period. Climate variables are from CRU TS 2.0, which provide them at a 0.5 x 0.5 grid resolution; grids were averaged proportional to their coverage of the administrative region.***
OLS regression; cluster-robust standard errors by country in parentheses; regions weighted by number of height measurements (mean: 204, std dev: 192).
**** p<0.10, ** p<0.05, *** p<0.01.***

Heights and economic development 1880-2000

There is overwhelming evidence that heights do respond to economic conditions on the African continent. As such, height trends give important insights into development processes.

We are still far from a general picture of height development in Africa in the late 19th, early 20th century, but so far height trends point to a more optimistic view of colonial times. African farmers benefitted from the cash crop revolutions. Cogneau & Rouanet (2011) found heights to increase in cocoa growing regions of Cote d'Ivoire. The same result was found for Ghana (Jedwab & Moradi, 2012). In Kenya heights of major population groups increased 1900-1980 (Moradi, 2009). African pastoralists, in contrast, are among the losers (Little & Gray, 1990). The famous Maasai, for example, are now shorter than 100 years ago. Reduction in grazing lands, limitations on movements, and droughts threaten their livelihood.

With regard to the post-1950 period, Moradi (2010a) found economic growth to be the best predictor of changes in mean height in women. The debt crisis and economic difficulties of the mid 1970s and 1980s reduced mean adult height of cohorts born during the crisis as well as those who experienced the crisis at puberty. The falling heights in most of SSA stand in striking contrast to the worldwide upward trend in heights in the second half of the 20th century.

Throughout the West during the 19th century we find a lower height of city dwellers. The urban penalty was mostly a result of poor public health due to overcrowding and poor water supply, sanitation, etc. With the advance in medical knowledge in the 20th century the penalty turned into an advantage. In contemporary survey data we find urban dwellers taller than their rural counterparts throughout Africa (Menon *et al.*, 2000).

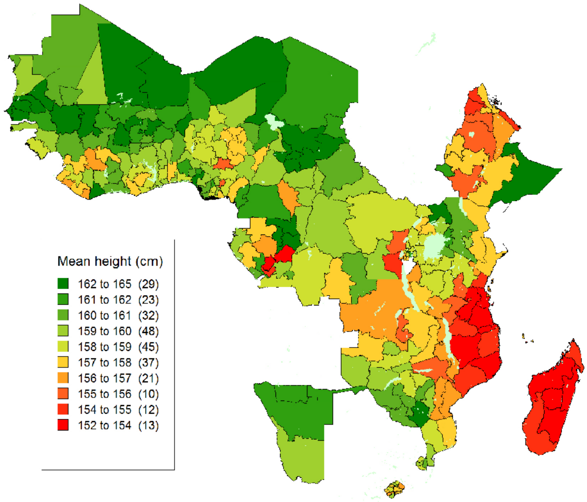

Fig. 2 - Mean height of women, 10 year-birth-cohorts born ca. 1965. See notes below Tab. 1. N (countries/administrative regions)=33/275.

Conclusions

National income is a weak predictor of mean height levels in African populations, because of a rather low correlation with the proximate causes of body growth. Climate instead fundamentally influences food intake and exposure to diseases. We hypothesize that a more favourable disease environment at adolescence allows catch-up growth at puberty, eventually leading to the tall adult heights we can observe in SSA. Overall, heights are responsive to changes in income. We therefore expect the anomaly in the height-income relationship in the cross-section to disappear in future.

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