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Health Human Capital in Sub-Saharan Africa: Conflicting Evidence from Infant Mortality Rates and Adult Heights

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Abstract

We investigate trends in cohort infant mortality rates and adult heights in 39 developing countries since 1960. In most regions of the world improved nutrition, and reduced childhood exposure to disease, have lead to improvements in both infant mortality and adult stature. In Sub-Saharan Africa, however, despite declining infant mortality rates, adult heights have not increased. We argue that in Sub-Saharan Africa the decline in infant mortality may have been due to interventions that prevent infant deaths rather than improved nutrition and childhood morbidity. Despite declining infant mortality, Sub-Saharan Africa may not be experiencing increases in health human capital.

Keywords

adult height; physical stature; human capital; Sub-Saharan Africa; disease burden; infant mortality rate

1. Introduction

Over the last fifty years the world has seen enormous improvements in population health in terms of falling mortality rates creating large improvements in human welfare (Becker, Philipson, and Soares 2005). Improvements in mortality in Europe and North America in the 19th century were associated with improved nutrition and public health measures, such as the provision of clean water and sanitation (Cutler, Deaton, and Lleras-Muney 2006, McKeown 1983). These mortality improvements went hand in hand with reductions in childhood morbidity and improved childhood nutrition, leading to increases in adult stature (Fogel and Costa 1997, Komlos 1998, Alter 2004). Crimmins and Finch (2006) show that in Europe the cohorts that experienced the largest gains in mortality as infants were the same as experienced the largest gains in adult height and the largest reduction in adult mortality.

There is increasing evidence that childhood health and nutrition can have a substantial impact on both physical and cognitive development, and eventual health status and productivity as an adult (Mendez and Adair 1999, Elo and Preston 1992, Hayward and Gorman 2004, O'Rand and Hamil-Luker 2005, Barker et al 1989, Kuh 2002, Yi, Gu, and Land 2007, Hoddinott et al 2008, Case and Paxson 2008, Victora et al. 2008, Schultz 2003a,

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2003b). In addition to the direct welfare gains from improved health we can also view health as a form of human capital insofar as healthier workers tend to be more productive. Nonetheless, health investments in children rather than in adults might be most important for human capital.

In addition to increasing worker productivity, improved health can also have more indirect effects on the economy; longer life spans can change life cycle behavior and the incentive to investment in human and physical capital. Reduced mortality will also influence population growth and age structure which may have effects on aggregate economic outcomes (Bloom and Canning 2000).

While there is increasing evidence that health is an important component of human capital, there is a mismatch in how health is measured at the individual and population levels. At the individual level we can use measures of individual well-being and morbidity, such as self reported health, anthropometrics, medical records, biomarkers for the presence of disease, or tests of specific abilities (Schultz 2005). At the aggregate level, however, we lack databases that provide summary statistics for these measures for populations. In cross country studies researchers usually use mortality rates (or some constructed indicator based on them, such as life expectancy) as their measure of population health (Bloom, Canning, and Sevilla 2004). It is clear that worker productivity is related to well-being and morbidity of living workers, not to mortality rates; nevertheless in macroeconomic studies, mortality indicators such as life expectancy are most often used as a proxy for the health of the living population.

This raises the question of whether the mortality measures used at the population level are related to the morbidity measures used at the individual level. Weil (2007) identifies this as a central issue in comparing household level and macroeconomic studies of the effect of health on the economy. He argues that if we assume that health is a one-dimensional construct, different measures of health should be closely related. He shows that in a small set of currently developed countries, for which a long time span of data is available, life expectancy and average adult height tend to move together over time. Individual level studies have found a strong connection between variations in adult height (due to differences in childhood health and nutrition) and wages (Schultz 2002, Schultz 2005). Weil uses the link between long run changes in height and changes in life expectancy, and the estimated effect of height on productivity, to calibrate the effect of improvements in life expectancy on the economy.

We extend this inquiry to consider if the link between reductions in mortality rates and improvements in adult height holds in developing countries during the last 50 years. We focus on infant mortality rather than life expectancy as our mortality measure. This is partially because it is child health that is central to adult well-being. It is nonetheless also the case that for most developing countries we lack comprehensive data on age specific mortality rates, apart from infant mortality rates, and life expectancy figures are based on mortality rates extrapolated from infant and child mortality using model life tables. This means that in practice, in many developing countries, reported life expectancy is a transformation of infant and child mortality (Deaton 2006). We compare evidence on infant mortality rate by year with the average adult height of women born in that year. Unfortunately we lack heights of men and there is no guarantee that male average heights move in the same way as female height (Klasen 1996, Moradi 2009).

Infant mortality and adult height depend on nutrition and the burden of disease experienced in childhood. While we have a measure on nutrition, we think of disease burden as a latent variable that affects both a cohort's infant mortality and its eventual adult height. In our theory section below we set out a model in which cohort infant mortality and eventual adult

height both depend on childhood nutrition and disease burden and show how this implies that a cohort's experience of infant mortality and average adult height should be linked.

We focus on comparing infant mortality over the period 1960–1985 with the adult height achieved by women born in those years. There is also the issue of how more recent experience of infant mortality is related to child under nutrition and stunting. We do not investigate this though Klasen (2008) has shown that in this case there are also puzzles, with child stunting being more prevalent in Asia than in Sub-Saharan Africa while Sub-Saharan Africa has higher infant mortality rates. Gräb and Priebe (2009) find high infant mortality despite low levels of stunting in the Lake Victoria region of Africa.

In section 2 we set out our theory of how nutrition and the disease environment in childhood affect both the infant mortality rate and eventual adult height. In section 3 we discuss our data set. We use data on the infant mortality rate and average female adult height for cohorts born between 1960 and 1985 in 39 developing countries (24 in Sub-Saharan Africa and 15 non Sub-Saharan Africa countries). In section 4 we estimate the relationship that links a cohort's infant mortality rate and its adult height and investigate the extent to which they tell the same story about trends in childhood health. Section 5 concludes.

2. Height and Infant Mortality Rates as Health Indicators

Cohort heights have been used by economic historians (Fogel 1993, Komlos 1993, Steckel 1995) as measures of “biological standard of living” when other indicators have not been available. It has been suggested that height can also be used as an indicator of health status in modern populations (Komlos and Lauderdale 2007). Steckel (2009) provides a recent survey of work in the social sciences using height as an indicator while Steckel (2008) discusses heights and mortality rates as measures of well being. Several studies have investigated the link between childhood health, nutrition, and adult height at the population level. Across developing countries, greater average protein intake is associated with greater average adult height (Jamison, Leslie, and Musgrove 2003). In addition, recent data has been used to examine the determinants of adult height in Sub-Saharan Africa (Moradi 2010, Moradi and Baten 2005, Deaton 2007, Akachi and Canning 2007).

Physical growth during childhood and adolescence, and the adult height that it ultimately leads to, is an indicator of childhood nutrition and the disease environment. Although height has a genetic component (McEvoy and Visscher 2009, Visscher et al 2006)¹, it is also significantly affected by childhood living conditions. The major proximate determinants of height are nutrition, disease environment, and work intensity (Tanner 1992, Peck and Lundberg 1995, Steckel 1995, Brush, Harrison, and Waterlow 1997, Stephensen 1999). The disease environment matters for physical development because infection can reduce appetite, and cause diarrhea and other health conditions that prevent absorption of nutrients and physical growth. The more distal socioeconomic determinants of height include such factors as income, inequality, public health measures such as water and sanitation, access to health care, personal hygiene, health technologies, labor organization, cultural values, and food prices.

We assume that adult heights depend on nutrition intake and the morbidity experienced in childhood due to the disease environment.² More formally, let us suppose average height, h_{it} , in country i at time of the cohort born at time t depends on a vector of variables x_{it} . This

¹At the individual level there is evidence from developed countries that as much as 80% of variation in the heights of individuals can be ascribed to genetic factors (Silventoinen 2003, Visscher 2006). Up to 20% of variation in body height is thus attributed to environmental variation in Western modern societies (Silventoinen 2000, Stunkard 1986). In poorer environments, this proportion is likely to be larger, with lower heritability of body height as well as larger social economic body height differences.

vector includes genetic endowment and other environmental conditions when the cohort is young. We single out childhood nutrition n_{it} and childhood disease burden, d_{it} , as factors influencing height. We then assume that height of the cohort born in year t in country i is determined according to the equation

$$h_{it} = \alpha_x x_{it} + \alpha_n n_{it} + \alpha_d d_{it} + \varepsilon_{it} \quad (1)$$

where ε_{it} is an error term. We assume that the infant mortality rate in country i at time t also depends on the same exogenous³ factors (if the factors affecting height and infant mortality differ they can be included in the other equation with a coefficient of zero) and childhood health according to:

$$m_{it} = \beta_x x_{it} + \beta_n n_{it} + \beta_d d_{it} + u_{it} \quad (2)$$

where u_{it} is an error term. These equations can be regarded as a linearized version of the model of height and mortality proposed by Alter (2004). The difficulty with equations (1) and (2) is that childhood disease burden d_{it} is an unobserved latent variable. We can combine equations (1) and (2) by substituting for the latent variable d_{it} to give the relationships

$$h_{it} = \left(\alpha_x - \frac{\alpha_d}{\beta_d} \beta_x \right) x_{it} + \left(\alpha_n - \frac{\alpha_d}{\beta_d} \beta_n \right) n_{it} + \left(\frac{\alpha_d}{\beta_d} \right) m_{it} + \left(\varepsilon_{it} - \frac{\alpha_d}{\beta_d} u_{it} \right) \quad (3)$$

The height and infant mortality rate of a cohort will be linked because both are linked to the latent variable, childhood disease burden. Akachi and Canning (2007) estimate the model given by (3) using data from Sub-Saharan Africa and find a significant relationship between the infant mortality rate in childhood and adult height even after controlling for income and nutrition.

However equation (3) does not allow us to estimate the underlying disease burden. To do this we replace the unobserved latent variable in equations (1) and (2) with a country specific intercept and time trend specified by

$$d_{it} = d_{i0} + d_i t \quad (4)$$

This means that equations (1) and (2) can be written as

$$h_{it} = \alpha_x x_{it} + \alpha_n n_{it} + \alpha_d d_{i0} + (\alpha_d d_i) t + \varepsilon_{it} \quad (5)$$

$$m_{it} = \beta_x x_{it} + \beta_n n_{it} + \beta_d d_{i0} + (\beta_d d_i) t + u_{it} \quad (6)$$

We estimate the evolution of the childhood disease burden as a country specific fixed effect and linear trend. We assign the fixed effect and trend in height not explained by other

²The net nutrition approach would also include the effect of labor and other physical activity in childhood that consumes energy and reduces the remaining energy balance available for physical growth.

³We mean exogenous in the sense that there is not reverse causality from height and infant mortality rates to these variables. There is still the possibility of correlation with the error term due to omitted variable bias or measurement error.

variables to the disease burden. Similarly we explain the fixed effect and time trend in infant mortality not explained by other factors to this same latent variable. In principle, equations (5) and (6) can give us two independent estimates of the level and time trend in the disease burden. We produce these estimates below and compare the results from the two regressions. If our model is correct, and we control properly for other factors affecting height and infant mortality, the estimates of the levels and trends in disease burden for each country produced by equations (5) and (6) using data on adult heights and infant mortality respectively should be similar.

An important question is what extant variables to add to the model in the vector x_{it} that may help explain infant mortality and adult height. We estimate a range of models including different sets of control variables. We begin with estimates that do not include any additional variables, even nutrition. In this case we are essentially assuming that there is a single latent variable, child health, which is the only factor influencing infant mortality and height. In this case, we see if the raw, unadjusted, data on infant mortality rates and adult height display the same pattern over time and across countries. Omitted variables in the model will mean that estimates of child health from height and infant mortality do not agree. We investigate what variables are required as additions to the model to bring the implied measures of child health, and disease burden into agreement.

We also estimate equations (5) and (6) adding average protein consumption, and average calorie consumption, in the cohort's year of birth as explanatory variables that proxy the cohort's food consumption. This removes variations in height and infant mortality due to these nutrition factors and we can see if the remaining variations in height and infant mortality, due to disease burden, move together. This approach mirrors Alter (2004) who thinks of food consumption and disease environment as the two factors influencing height and infant mortality. We can regard our estimates of child health for our unadjusted model as combining the effects of nutrition and the disease environment. Once we adjust for nutrition our latent variable is a measure of the disease environment.

There are several possible omitted variables from our model that should be captured by the vector x . One possible set of omitted variables is genetic variations in population height. These genetic variations may produce differences in height across populations. However, if we assume that these variations are fixed over the short time period we consider so that they may affect the country fixed effects in equation (5) but not the country specific time trends. A second potential omitted variable is technological progress in mortality reduction. At each level of child health there may be reductions in mortality over time due to the introduction of new life saving interventions. If these technologies save lives, but leave the underlying health condition and morbidity unchanged, there may be a time trend in equation (6) that is not reflected in heights. Both these potential omitted variables will reduce the correlation between heights and infant mortality rates unless we control for them.

A third set of omitted variables comes from the fact that while infant mortality rates are determined by factors in the year of birth, adult height may be influenced by things that occur after the first year of life but before full adult stature is achieved. While physical growth is very sensitive to disease and nutrition in the first year of life, illness and food intake later in childhood also matter. We control for these later childhood influences by adding the average annual infant mortality rate, and intake of calories and protein, in the country over the years when a cohort is aged between 1 and 18 years as additional explanatory variables in determining its adult stature. Note we do not add these explanatory variables in the infant mortality equation since they occur after age one.

A fourth set of omitted variables concerns the distribution of food intake, and other inputs, across children. If the model at the individual level is linear, there will be a linear relationship between population averages at the aggregate level. Nevertheless if the underlying model at the individual level is non-linear then, in the aggregate, health outcomes will depend on the distribution of food as well as the average level. We do not model the distribution of nutrition, but attempt to capture it with country fixed effects on the assumption that the distribution in each country is stable over time.

3. Data

The height data we use are for women and come mainly from Demographic and Health Surveys (DHS), though we also use Family Life Surveys (FLS) for Mexico and Indonesia. All Demographic and Health Surveys available at the time of analysis that include female height as a variable were employed in this analysis. Height in Demographic and Health Surveys is measured by the interviewer, using a headboard. The typical Demographic and Health Surveys dataset contains the heights of women from age 15 to 49 for a nationally representative sample. We use the sampling weights provided to construct an average height for cohorts by birth year. We only use heights of women aged 20 and above on the grounds that at age 20, physical growth has usually ceased.

One complication is that in earlier surveys, only the heights of mothers with children under age 5 were measured, while in later Demographic and Health Surveys the height of all women 15 to 49 was measured. This creates a sample selection problem since mothers are not a random sample. For example, if higher socioeconomic status is associated with fewer children, and height is positively linked to socioeconomic status, then the average height of mothers may be lower. For data consistency, we examined the average height of each cohort as measured in different DHS surveys and found them to be remarkably similar, independently of whether the data were for all women or just mothers. These findings agree with those of Moradi (2010), who argues that there is little selection bias due to this issue in developing countries because the vast majority of adult women have children.

In total, we have height data from 39 countries, 2 from FLS and 37 from DHS. The Sub Saharan Africa countries are: Benin, Burkina Faso, Cameroon, Central Africa, Chad, Cote d'Ivoire, Ethiopia, Gabon, Ghana, Guinea, Kenya, Madagascar, Malawi, Mali, Mozambique, Niger, Nigeria, Rwanda, Senegal, Tanzania, Togo, Uganda, Zambia, and Zimbabwe. Countries outside of Sub-Saharan Africa are: Bangladesh, Bolivia, Brazil, Colombia, Dominican Republic, Guatemala, Haiti, India, Indonesia, Mexico, Morocco, Nepal, Nicaragua, Peru, and Turkey.

Table 1 gives descriptive statistics for our dataset. We also give descriptive statistics and distributional tests for the heights for cohorts born in 1960, 1965, 1970 and 1975 from the Bangladesh 2004, Bolivia 2003, and Ghana 2003 DHS in Table 2 to help the reader get a sense of the data. The standard deviation of individuals' heights is around 6 centimeters; this distribution of heights is fairly uniform in all the samples we use. There is some evidence of a positive (right) skew in the distribution of recent cohorts for Bangladesh and Bolivia DHS while there appears to be a negative skew for the distribution in Ghana. Positive kurtosis (so that the peak of the distribution is higher and narrower, with fatter tails, than the normal) was observed for each cohort for all three country DHS. Tests of the hypothesis that the distribution is normal fails to be rejected for the three 1960 cohorts and 1970 Ghana cohort, but it is rejected for the other cohorts. Figure 1 shows the estimated distribution of heights of the cohort born in 1970 in Ghana 2003 DHS. The rejection of normality was common in many of our datasets. The deviation from normality could due to a selection effect or a skewed distribution in health and nutrition (Jacobs, Katzur, and Tassenaar 2008).

We construct average height for each cohort by year of birth from each survey. For countries with multiple DHS surveys, cohort heights by birth years were graphed to check for consistency when the same cohort is included in different surveys. The example for the three DHS surveys of Ghana is shown in Figure 2, and that of Bolivia in Figure 3. Glick and Sahn (2008) find that there is evidence of changing estimates of cohort height for urban and rural women in Kenya and Ghana in different DHS surveys, but this may be due to rural-urban migration over time. Looking at Figure 2 for Ghana we do see some variation of height by year of birth in different DHS surveys, but it does not appear to be systematic across years; we attribute the difference to sampling error which we reduce by averaging across countries⁴. In most cases the results for average height by birth cohort using different surveys were very similar. The only country in which we found considerable variation was Egypt⁵.

In order to calculate average cohort height we average over available DHS surveys for each country when multiple surveys are available. This gives larger sample sizes except at the beginning and end of the series where often only data from one survey is available. Larger sample size reduces the standard error in the cohort average and result in noticeably lower volatility in average heights. The number of observations for each cohort from a survey is used as a weight in taking the averages for a cohort across different surveys.⁶ Countries with a single DHS survey give about 30 years of cohort data (women aged 20 to 49 are sampled to create cohort heights). For countries with multiple DHS surveys we get longer time spans of cohort height data though most of the information gained from using additional surveys is in additional observations of women's height from the same cohort.

We compare heights with indicators for infant mortality and nutrition. We use the infant mortality rate from the World Bank's World Development Indicators (2005), with data going back to 1960. We interpolated the infant mortality rate over gaps of up to two years to derive an annual time series. For nutrition we use daily average consumption of calories and protein from the World Food Organization FAOSTAT database, with data going back to 1961. The Food and Agriculture Organization (FAO) (2006) food balance sheets calculate the consumption of each foodstuff. Food consumption is calculated in two ways: aggregate estimates based on production plus imports, minus exports, stock changes, and non food uses such as animal feed, seed, waste, and input to manufactures, and household levels estimates using data on food consumption from household surveys. The FAO attempts to reconcile the two approaches. Calories and Protein consumed per capita are calculated from national consumption of each food item using nutritional tables of calorie and protein content, and dividing by the population. These estimates for national food or nutrient availability do not account for the distribution of food or nutrient supply between regions with a country or among other groups of households. The data we use provide daily average consumption of calories and protein for each country by year from 1961 to 2002.

Jacobs and Sumner (2002), discuss the construction of the FAO food balance sheets, problems in constructing the data, and their appropriate use. Svedberg (2000, 2002) argues that implied level of malnutrition in Sub-Saharan Africa based on FAO data is implausibly high, and is not matched by exceptionally low heights or weights for children in the region. This may be due to the fact that the FAO estimates fail to count a large percentage of food production used for subsistence in the region. Our data also suffers from this problem.

⁴With a standard deviation in height of about 6cm across individuals and sample size of around 150 per birth year we would expect a 95% confidence interval of approximately 1cm in either direction on the estimated cohort average height.

⁵Egypt has three DHS surveys. The 2003 survey gives heights for each cohort that consistently higher, by about 2 cm, than found in the 1995 and 2000 surveys. We are uncertain of the reason for this difference, and the surveys from Egypt were discarded.

⁶We calculate the average height of a cohort from each survey using its sampling weights and then combine averages for the same cohort from different surveys weighting by the sample size of the cohort in the survey.

Nonetheless our main specification uses fixed-effects which imply that the mean level of food consumption does not affect our health measures; we identify the effect of changes in food consumption on changes in health. If the measurement error in food availability is constant over time, and if the changes in estimated food availability match actual consumption, our results will be robust.

We begin by investigating the link between physical development, infant mortality, and nutrition, looking at how these change over time in developing countries. Table 3 gives the time trends for infant mortality rates, protein, and calorie intake for countries in Sub-Saharan Africa, from 1961 to 1985, matched with the trends in adult height for cohorts born during that period. In every country in the region except Rwanda, there are statistically significant declines in the infant mortality rate. In terms of protein and calorie intake, the pattern in Sub-Saharan Africa is much more mixed: as many countries have experienced declines in nutritional intake as have increases. Furthermore, adult heights have risen significantly in none of the countries, whereas ten countries, Central Africa, Chad, Ethiopia, Madagascar, Mozambique, Nigeria, Rwanda, Tanzania, Uganda, and Zambia, have experienced heights decrease. We emphasize that these patterns are for women over the period 1961–1985. Over the period since 1920 there is evidence of substantial gains in male heights in several African countries (Moradi 2009, Cogneau and Rouanet 2009).

We can compare these trends with those in some developing countries outside Sub-Saharan Africa over the same time period, shown in Table 4. Infant mortality rates declined significantly in every country outside Sub-Saharan Africa. Nutrition in the form of either calorie or protein intake increased significantly in all countries except Bangladesh and Peru. Adult heights also increased significantly in majority of the countries including Bolivia, Colombia, India, Indonesia, Mexico, Morocco, Nicaragua, Peru, and Turkey. We observed stagnancy in other countries, but none of the time trends outside of Sub-Saharan Africa region were significantly negative.

These regional trends are summarized in Table 5. In terms of infant mortality, we find similar rates of decline in Sub-Saharan Africa and developing countries in other regions: a decrease of about 2.1 versus 2.3 infant deaths per thousand live births each year.⁷ On the other hand, while both protein and calorie consumptions have been increasing significantly elsewhere, within Sub-Saharan Africa protein and calorie consumption remained virtually unchanged over the whole period or even declined. The trends in height are also quite distinct. In Sub-Saharan Africa, heights overall have been decreasing; the cohort born in 1985 is about 0.5 centimeters shorter than the cohort born in 1961. In contrast, in the rest of the developing world, the height of adult women has risen by approximately 1.2 centimeters on average during this twenty-four year period.

There is a serious concern over measurement error in our variables. Average heights are based on sample surveys and will have sampling error as well as errors due to age misreporting (we find evidence of age heaping in the data). Infant mortality rates are interpolated and in this period are often based on weak underlying data (Bos, Vu, Stephens, and Patience, 1992). Our nutrition measures may also be flawed. These measurement error problems will bias our results. Our main results, however, are in terms of differential time trends in these variables, and it may be that even if there are biases in the levels measured, effect of measurement error on time trends is much less.

⁷We average over countries treating each as an observation rather than construct population weighted averages.

⁸This estimate is based on 1961–1985. Using the same dataset, Adetunji and Bos (2006) finds that in Sub-Saharan Africa as a whole, infant mortality rates declined from 149 per 1,000 live births in the 1960s to about 101 in 2005, or annual change about 1.2, about half our estimate. The difference in the estimates is likely due to the HIV/AIDS epidemic that affected the regions since the 1990's during which the decline in infant mortality stagnated.

4. Results

As in Weil (2007) we find little connection between infant mortality rates and adult heights across countries. Adult Africans are tall compared to people in other countries with similar incomes, despite apparent poor nutrition and high mortality rates when young. We argue that these cross country differences in height are due to unobserved fixed factors, not child health. These country fixed effects could to some extent reflect genetic differences between people in different countries. There is evidence that greater genetic variation exists between humans in Africa than in other regions, because of Africa's large historical population while humans in other continents are mainly descendents of small migrant groups that have less diversity (Relethford and Harpending 1994). Nonetheless other factors, such as selection effects (Deaton 2007, Bozzoli, Deaton and Quintana-Domeque, 2009), underestimation of nutrition (Svedberg 2000, 2002), or the distribution of resources (Moradi and Baten 2005) could play a large role. At present we are not in a position to definitively identify the reasons for the lack of consistent relationship between the level of infant mortality and adult height.

When we examine trends in cohort infant mortality rates, and average adult height, over time, within countries, we find a strong correlation; the countries with the greatest improvements in infant mortality are also those with the largest increases in average adult height. We ascribe this common movement to the effect of changes in underlying child health. Obviously this conclusion may be overturned if some variables we omit were added to the model and we find that infant mortality rates and adult height have very different determinants that just happened to move together during the period, and that their common movement was by chance.

While all countries in our sample have showed falling infant mortality rates, we find that in Sub-Saharan Africa as a whole, adult heights have not been increasing, and in some countries we even see significant declines in height. Most developed countries underwent a transition in which infant mortality fell and adult height increased. We argue that this pattern continues to hold true today in much of Latin America and Asia where reductions in infant mortality go hand in hand with improved nutrition, reductions in child morbidity, and increases in adult heights. In Sub-Saharan Africa, however, we find a distinctively different pattern: while infant mortality has been falling, adult heights have been stagnating, or even declining, over the last 50 years. This undermines the view that since infant mortality rates have been falling, health human capital has been rising. There has been no improvement in health human capital, as measured by height, in the region.

One possible reason behind the divergent trends in infant mortality and adult height in Sub-Saharan Africa is the source of the infant mortality reductions in the region. In most other regions of the nutrition, as measured by energy (calorie) or protein intake per person, has been increasing. Sub-Saharan Africa in contrast has experienced little in the way of increases in nutrition. Rather than broad based improvements in nutrition and public health measures such as access to clean water and sanitation, mortality reduction in Sub-Saharan Africa appears to have occurred through health interventions measures that directly reduce mortality with limited effect on disease prevalence, morbidity, and the physical development of children.

The idea that reductions in infant mortality in Africa have not been associated with improved health in surviving children has been suggested before. Huffman and Steel (1995) and Guerrant, Carneiro-Filho, and Dillingham (2003) argue that oral rehydration therapy and measles vaccination have large effects on infant mortality rates, while morbidity rates remain high and the physical development of children continues to be impaired. Greenwood et al (1987) finds little improvement in the stunting and wasting of children in rural Gambia,

despite high levels of vaccination coverage and few deaths due to vaccine preventable diseases. Similarly, Pinchinat et al. (2004) find that vaccination and malaria prevention in Senegal improve childhood survival but do not improve the health status of living children. These researchers attribute the persistent high child morbidity rates, despite improvements in child mortality, to continuing acute respiratory infections, malaria, chronic diarrhea, and malnutrition. Our research suggests that health is multi-dimensional, and that changes in infant mortality rates and adult heights, while tending to move together overall, may diverge significantly in some regions. Improvements in infant mortality in Africa may not be indicative of broad based improvements in population health and health human capital.

We begin by estimating equation (3). If our theory is correct there should be a relationship between the infant mortality rate and adult height, after controlling for other variables. Results estimating this link are given in Table 6. In column 1 of Table 6 we estimate the effect of the infant mortality rate in a cohort's year of birth on the height of that cohort. Estimation is by weighted least squares in which we weight each observation by the number of observations used to calculate the cohort's average height. A larger number of observations reduces the random sampling error in estimated cohort height and gives more reliable figure. We find a positive coefficient on infant mortality indicating that cohorts that experience a higher infant mortality rate when young are taller as adults⁹; this counterintuitive result is likely due to omitted variable bias since we do include the other relevant variables in the model.

In column 2 of Table 6 we re-estimate the relationship with country fixed effects. We now find a significant negative coefficient on infant mortality. Within countries, cohorts that experience low infant mortality rates as children are taller as adults. There is little we can infer from the fixed effects. In principle, they represent country specific, time invariant, omitted variables that affect height. They may reflect genetic differences between the populations, but genetic effects alone may unlikely be the sole cause of these significant fixed effects. The country fixed effects could be capturing factors such as institutions, culture, or climate, that are relative steady over time within a country and affect health but which we have omitted from the model.

In column 3 we add calorie and protein consumption per capita in the cohort's year of birth as control variables. We find that within countries the tallest cohorts are those that had low infant mortality and high levels of protein consumption in childhood. Protein is often considered as the most important single nutrient affecting growth (Zerfas 1986, Allen 1994, Martorell & Habicht 1986). Martorell (1976) argues that the relative contribution of calories and proteins to the association depends upon which nutrient is limiting in the current diet. The correlation between protein and calorie intake is high (0.822) in the data.

In column 4 of Table 6 we include a time trend (taken to be the same in each country) to allow for technical progress that might change the relationship between the disease environment and infant mortality. We find a significant negative time trend in heights though the significant effect of childhood infant mortality and protein remain. We do not think there is really a downward trend in heights over time. Rather, as we shall see below, there appears to be time trends in infant mortality that are not reflected in heights. In column 5 of table 6 we add the average IMR, calories and Protein over ages 1–18. We find that average IMR in later childhood is a significant predictor of adult height. However, the infant mortality rate in the year of birth remains significant in column 5. The results in Table 6 suggest the relationship between infant mortality and adult height is in the expected

⁹This corresponds to the fact that Sub-Saharan Africa has the highest infant mortality rates, but also the tallest adults (Deaton, 2007). Deaton, A. 2007. "Height, health, and development." *Proceedings of the National Academy of Sciences* 104: 13232–13237.

direction once we control for country fixed effects. The results on the relationship between infant mortality and adult height are similar to those in Akachi and Canning (2007) who focus only on Africa.

We now turn to estimates of child health and disease based on our data on infant mortality and heights. We begin with the model set out in equations (5) and (6) without any additional controls. That is, we regress cohort height by year of birth on country fixed effects and time trends and then do the same for the infant mortality rate. This gives us an estimated initial level and time trend for each variable in each country. We do not report the initial levels for each country but the time trends in height and infant mortality are as reported in Table 3 and 4. We plot the initial levels of infant mortality against the initial level of height (using the country specific fixed effects for each country) are reported in Figure 4. There is no evidence of a relationship. On the other hand, at each level of infant mortality, women in sub-Saharan Africa are taller than in the rest of the developing countries. Obviously if we take the level of infant mortality and average female heights as our two measures of population health, the two measures do not agree.

In Figure 5 we plot the time trend in infant mortality against the time trend in height for each country. A positive time trend in height would be evidence of increasing child health. We think of a negative time trend in infant mortality also as evidence of increasing child health. There is a strong relationship between decreases in infant mortality and gains in height. Both Sub-Saharan African countries and non Sub-Saharan African countries follow the same relationship in trends. Nonetheless Sub-Saharan African countries tend to have smaller declines in infant mortality than in other regions, and it tends to have decreasing rather than increasing heights. Adult heights and infant mortality rates imply that they are telling us the same story about child health in terms of the ranking of countries. Outside Sub-Saharan Africa, both indicators provide evidence of improvements in child health insofar as mortality trends tend to be negative while height trends tend to be positive. In contrast, in Sub-Saharan Africa, falling infant mortality rates indicate improving child health while decreasing adult heights suggest declining child health.

The difference in implied child health from the two measures in Sub-Saharan Africa, both in levels and in changes, indicates that we have unobserved variables that are affecting the outcomes. We therefore estimate equations (5) and (6) adjusting for covariates x_{it} . The country fixed effects, and time trends in (5) and (6), after adjusting for these covariates, should collaborate one another.

We begin in Table 7 by estimating equation (5) for adult height. In column 1 of Table 7 we control for calorie and protein consumption per capita in the year of birth. While protein consumption has a positive effect on heights, the coefficient on calorie consumption is negative and significant. However, column 1 does not control for country fixed effects – the result is due to the fact that in Sub-Saharan Africa people are tall despite having very low calorie consumption in childhood. In column 2, controlling for country fixed-effects, we find a positive effect of calorie consumption while protein consumption is not statistically significant. This seems more reasonable and suggests that when childhood calorie consumption rises over time later cohorts are taller.

In column 3 of Table 7 we add a common global time trend, but this is not significant. Once we control for nutrition there is no trend in heights. In column 4 of Table 7 we add as additional factors that may affect adult height: the average IMR, protein and calories consumption over the age range 1–18 years. The long run trend in calorie consumption in a country explains the long run trend in height in that country. Nevertheless, short run movements in calorie consumption in the first year of life do not explain movements around

the trend. In columns 5 and 6 of Table 7 we add country specific time trends as well as fixed effects. Once the country specific time trends are added, all other variables are insignificant; the model is able to explain country time trends in height but not movements around the trend.

In Table 8 we repeat the analysis in table 6 but with the log infant mortality rate as the dependent variable. In columns 1 and 2, with and without fixed effects respectively, we find conflicting evidence on the effect of nutrition with higher calorie consumption appearing to lower infant mortality rates while higher protein consumption appears to raise them. This may be due to misspecification of the model and correlation between our nutrition indicators. In column 3, where we add a common global time trend, improvements in nutrition in either form lower infant mortality. Column 3 of Table 7 indicates that there is a long run trend towards lower infant mortality, with mortality rates falling about 1.8% a year across all countries independently of changes in nutrition. We think of this effect as technological progress in health care. Cutler, Deaton, and Lleras-Muney, 2006 ascribe much of the gains in mortality in the second half of the 20th century to improvements in health technology rather than better direct health inputs such as nutrition or health care. In column 4 of Table 7 we add country specific time trends and find higher calorie consumption still improves mortality outcomes.

In Figure 6 we plot the country specific fixed effects in height from column 5, Table 7, against the fixed effects in IMR from column 4 in Table 8. Even after controlling for other variables as in these regressions there is no clear relationship between the level of IMR and adult height across countries. Since we adjust for nutrition, and later influences on height, we can think of these fixed effects as representing the disease burden in the year of birth. As in Figure 4 there is little evidence of a relationship, though people in Sub-Saharan Africa tend to be taller than people elsewhere at each level of disease burden as indicated by infant mortality. The lack of correlation between average adult height and the level of infant mortality makes it difficult to think of these as both being due to a single common factor, the disease burden¹⁰.

In Figure 7 we plot the time trends from the regressions in column 5 of Tables 7 and column 4 of table 8. The time trends in height and infant mortality move together, even after controlling for nutrition and later childhood factors. While they are highly correlated the height data suggest declining health due to disease in the first year of life while the infant mortality rate data again suggest improving health. In Figures 8 and 9 we replicate Figures 6 and 7 but now using the results from column 6 of Table 7 for height, though we still use the results from column 4 of table 8 for IMR. In these figures we are adjusting not only for childhood nutrition but later childhood influences on adult height. The results are, however, very similar to before; we see little relationship between the level of IMR and adult height, and a close correlation in time trends.

While the time trends in adult height and IMR (after allowing for our explanatory variables for the regressions) in Figure 9 are highly correlated, they tell different stories, with IMR trending downwards while adult heights are generally declining in Sub-Saharan Africa. One way of reconciling these results is to argue that the worldwide time trend in infant mortality found in column 3 of Table 8 reflects technological progress in preventing mortality in a given health state. We found no evidence of a time trend in height after adjusting for nutrition in column 3 of Table 7, which is consistent with no technological progress in turning nutrition into height. If we subtract the worldwide technological progress estimated

¹⁰The lack of correlation will remain if we linearly transform the variables, so it is not a matter of simply calibrating two different measures of the same underlying variable to match each other.

in column 3 of Table 8 from the country specific time trends of infant mortality found in the regression in column 4 of Table 8 we get the result plotted in Figure 10. Taking out technological progress in infant mortality, the evidence on the disease burden from trends in infant mortality and trends in height agree quite well across countries.

Our results suggest that we still have omitted variables in levels when we compare heights and infant mortality rates. It may be risky to compare across countries using these measures as indicators of health human capital. We leave open the question of what variables would need to be controlled for to make the cross country comparisons feasible. On the other hand, once we control for nutrition and worldwide technological progress in infant mortality, country specific time trends in cohort height and infant mortality rate agree well. Our theory suggests this because, once we have controlled for these additional variables, both measure the same latent variable, the disease burden on children.

We could go further, and add additional control variables to our model, such as income per capita. Nevertheless income per capita may be correlated with the provision of medical and public health services that lower the disease burden. Controlling for this will reduce the information content on disease burden in our latent variable. There is a risk of including too many variables in equations (5) and (6); we want to control for variables that affect height and infant mortality but are not themselves determinants of, or proxies for, the burden of childhood disease.

5. Conclusion

In most of the developing world, and in the historical record of developed countries, there has been a steady advance in infant mortality rates, improvements in nutrition, and increases in adult height, with all of these developments proceeding together. In Sub-Saharan Africa, however, a very different pattern unfolds. While there have been large reductions in infant mortality, nutrition intake and adult stature have not improved.

The health transition in terms of mortality-morbidity taking place in Sub-Saharan Africa appears to be driven by medical interventions that reduce mortality, rather than by nutrition improvements and broad based reductions in exposure to infectious diseases that would reduce morbidity. This has several implications. It reinforces the view that population health is multidimensional. Movements in mortality measures, such as infant mortality rates and life expectancy, may give a limited insight of how broader population health is changing.

This has implications for studies of the effect of health on worker productivity. In macroeconomic studies of the effect of health on economic growth (Bloom, Canning, and Sevilla 2004) life expectancy or adult mortality rates are often used as measures of population health, assuming that these measures are closely linked to adult height (Shastri and Weil 2003) as used in microeconomic studies (Schultz 2002). This assumption may be unwarranted unless the infant mortality rate is adjusted to take account of country specific fixed effect and a world wide time trend due to technological progress in mortality reduction.

Our results also call into question the practice of focusing on the use of mortality rates as the sole indicators of population health. For example the Millennium Development Goals (MDGs) focus on reducing mortality, but our results suggest that mortality rates can improve through new technologies that prevent deaths while underlying health problems due to poor nutrition and a high burden of morbidity worsen. Nutrition has been seen as the “forgotten” MDG11 and may have benefits both in terms of reducing infant mortality and in increasing the stature and health human capital on the next generation of adults. In other words, reducing stunted children should be included in the MDG goal.

Finally, the continuing child morbidity and lack of physical development may be significant for the future of the aging population in Sub-Saharan Africa. While the African population is aging (National Research Council 2006), there is strong evidence that the health of adults and the elderly is affected by their childhood health and nutritional status (Barker et al 1989, Fogel and Costa 1997, Catalano and Bruckner 2006, Brush, Harrison, and Waterlow 1997, Blackwell, Hayward, and Crimmins 2001, Yi, Gu, and Land 2007). This suggests that the lack of nutrition and high levels of morbidity among children in Sub-Saharan Africa, and declining adult stature, may be producing unhealthy adults and a growing future health burden.

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¹¹World Bank, 2008:
<http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:21627646~pagePK:34370~piPK:34424~theSitePK:4607,00.html>

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Figure 1.

Figure 2.

Bolivia DHS Comparison **Figure 3.**

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Estimates of the time trend in disease burden 1960-1985 adjusting for childhood nutrition

Figure 9.

Figure 10.

Table 1

Descriptive Statistics

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Average Cohort Height (cm)	749	156.687	3.687	147.330	164.436
Infant Mortality Rate I2 (per 1000 births)	1442	1.149	0.405	0.230	2.858
Calories (calories per day)	1442	2189.924	334.814	15.100	35.390
Protein (gram per day)	1442	55.314	11.892	0.301	1.030

¹²Interpolated over 1 year to 2 years

Table 2

Descriptive Statistics and Distributional Tests

Birth Cohort	1960	1960	1970	1975
Bangladesh DHS 2004				
Observations	201	285	368	396
Mean height	149.96	150.50	150.33	150.62
Standard Deviation	5.35	5.60	5.60	5.82
Skewness	−0.218	0.372	0.482	0.807
Kurtosis	2.63	4.16	4.24	6.33
Normality test: Shapiro-Wilk p-value	0.17	0.0012	0.0007	<0.00001
Bolivia DHS 2003				
Observations	376	440	496	538
Mean height	150.93	151.29	151.75	151.71
Standard Deviation	5.72	6.38	5.91	5.91
Skewness	−0.03	0.43	0.36	0.26
Kurtosis	3.42	4.29	3.20	4.02
Normality test Shapiro-Wilk p-value	0.215	0.00004	0.002	0.0005
Ghana DHS 2003				
Observations	102	144	151	187
Mean height	158.59	159.61	160.04	158.57
Standard Deviation	5.36	7.27	5.97	6.92
Skewness	0.23	−2.44	−0.08	−2.49
Kurtosis	2.56	20.90	2.90	21.27
Normality test:Shapiro-Wilk p-value	0.41	0.0001<	0.93	0.0001<

Table 3

Time Trends in Adult Height, Infant Mortality, and Nutrition Sub-Saharan Africa, 1961– 1985

Country	Adult Height (cm)	Infant Mortality Rate (deaths per 1,000 live birth)	Calories (calories per capita per day)	Protein (grams per capita per day)
Benin (1996, 2001)	−0.025	−2.288 **	4.466	0.119
Burkina Faso (1998, 2003)	0.001	−2.126 **	0.643	−0.135
Cameroon (1998, 2004)	−0.031	−2.240 **	8.697 **	0.008
Central Africa (1994)	−0.093 *	−2.852 **	−2.321	0.180 **
Chad (1997, 2004)	−0.062 **	−2.945 **	−36.048 **	−1.360 **
Cote d'Ivoire (1994)	−0.032	−3.805 **	22.622 **	0.403 **
Ethiopia (2000)	−0.164 **	−1.772 **	−3.795	−0.391 **
Gabon (2000)	0.019	−4.331 **	27.524 **	1.076 **
Ghana (1993, 1998, 2003)	−0.042	−1.782 **	−18.089 **	−0.129
Guinea (1999)	−0.045	−2.169 **	−6.328 *	−0.051
Kenya (1993, 2003)	0.018	−2.237 **	−0.493	−0.319 **
Madagascar (1997)	−0.083 *	−0.300 **	0.118	−0.234 **
Malawi (2000)	−0.026	−2.425 **	3.552	−0.018
Mali (1995)	0.028	−5.329 **	−13.782 **	−0.404 **
Mozambique (1992, 2003)	−0.059 **	−1.786 **	−2.912 *	−0.155 **
Niger (1992, 1998)	−0.036	−0.785 **	19.282 **	0.577 **
Nigeria (1999, 2003)	−0.075 **	−0.300 **	−12.487 **	−0.280 **
Rwanda (2000)	−0.094 **	0.114	18.585 **	0.230 *
Senegal (1992)	−0.041	−2.752 **	−6.115	0.012
Tanzania (1996)	−0.070 **	−1.841 **	28.325 **	0.783 **
Togo (1998)	−0.042	−2.557 **	−9.458 **	−0.014
Uganda (1995, 2000)	−0.109 **	−0.952 **	−5.479	−0.124
Zambia (1996, 2001)	−0.071 **	−1.294 **	−0.272	−0.334 **
Zimbabwe (1994)	0.021	−1.493 **	1.673	−0.295 **

Coefficient of the time trend by country.

Coefficients represent per annum change, significance level indicated as *(5%), ** (1%).

Height trends estimated with weighted least squares; weighted by the number of individuals used to calculate the cohort average height. Years mentioned below country name are the years the DHS surveys used come from.

Table 4

Time Trends in Adult Height, Infant Mortality, and Nutrition Non Sub-Saharan African Developing Countries, 1961–1985

Country	Adult Height (cm)	Infant Mortality Rate (deaths per 1,000 live birth)	Calories (calories per capita per day)	Protein (grams per capita per day)
Bangladesh (1996, 1999, 2004)	−0.019	−1.422 **	−5.519 *	−0.0007
Bolivia (1994, 1998, 2003)	0.066 **	−2.339 **	15.255 **	0.357 **
Brazil (1996)	0.001	−2.277 **	18.466 **	0.217 **
Colombia (1995, 2000, 2005)	0.081 **	−2.185 **	16.721 **	0.152 **
Dominican Republic (1991, 1996)	0.045	−1.685 **	23.076 **	0.434 **
Guatemala (1995, 1998)	0.023	−2.131 **	13.117 **	0.091
Haiti (1994)	0.016	−1.934 **	3.085 **	0.185 **
India (1998)	0.047 *	−1.749 **	6.021 *	0.054
Indonesia (1993, 2000)	0.040 *	−2.394 **	28.626 **	0.753 **
Mexico (2002)	0.069 *	−1.992 **	37.350 **	0.950 **
Morocco (1992, 2003)	0.043 **	−1.934 **	30.844 **	0.734 **
Nepal (2001)	−0.006	−3.697 **	7.908 **	0.253 **
Nicaragua (1997, 2001)	0.039 **	−2.506 **	0.752	−0.331 **
Peru (1992, 1996, 2000)	0.092 **	−3.005 **	−2.154	−0.079
Turkey (1993, 1998)	0.112 *	−3.540 **	19.735 **	0.383 **

Coefficient of the time trend by country.

Coefficients represent per annum change, significance level indicated as *(5%), **(1%).

Height trends estimated with weighted least squares; weighted by the number of individuals used to calculate the cohort average height. Years mentioned below country names are the years the DHS surveys used come from, except for Indonesia and Mexico. These countries used nationally representative data from Family Life Surveys (FLS) instead of DHS, and the years correspond to FLS survey years.

Table 5

Regional Time Trends in Adult Height, Infant Mortality, and Nutrition, 1961–1985

Region	Adult Height (cm)	Infant Mortality Rate (deaths per 1,000 live birth)	Calories (calories per capita per day)	Protein (grams per capita per day)
Sub-Saharan Africa	−0.049** (0.005)	−2.094** (0.054)	0.746 (0.849)	−0.036 (0.026)
Other Developing Countries	0.056** (0.004)	−2.319** (0.038)	14.219** (0.786)	0.277** (0.022)

Coefficient reported on common regional time trend with country fixed effects.

Coefficients represent per annum change, standard errors in parentheses, significance level indicated as * (5%), ** (1%).

Height trends estimated with weighted least squares; weighted by the number of individuals used to calculate the cohort average height.

Table 6

Relationship between Cohort Height and the Infant Mortality Rate in Birth Year Dependent Variable: cohort average height (centimeters)

	1	2	3	4	5
Constant	155.339** (0.138)	150.963** (0.100)	149.337** (0.388)	152.012** (0.461)	167.698** (1.303)
Log infant mortality rate (per 1,000)	1.516** (0.359)	-1.483** (0.143)	-1.153** (0.171)	-3.557** (0.300)	-3.161** (0.362)
Energy consumption per capita (calories/100)			0.026 (0.034)	0.017 (0.032)	0.362 (0.033)
Protein consumption per capita (grams/100)			2.234* (1.135)	2.191* (1.069)	2.755* (1.122)
Average IMR					-1.581** (0.456)
Average calories					0.028 (0.063)
Average protein					0.223 (1.982)
Time					-0.090** (0.011)
Country fixed effects	no	yes	yes	yes	yes
R²	0.022	0.977	0.978	0.981	0.982
Number of observations	788	788	749	749	726

Based on data from 39 countries. Weighted least squares where weights are sample size used in calculation of average cohort height. Significance level indicated as *(5%), **(1%).

Table 7
Relationship Between Cohort Height and Nutrition in Birth Year Dependent Variable: cohort average height (centimeters)

	1	2	3	4	5	6
Constant	157.040** (0.935)	147.789** (0.323)	147.819** (0.325)	165.774** (1.354)	151.219** (0.633)	157.470** (2.877)
Energy consumption per capita (calories/100)	-0.349** (0.068)	0.133** (0.031)	0.121** (0.034)	0.022 (0.034)	-0.042 (0.040)	-0.033 (0.044)
Protein consumption per capita (grams/100)	10.971** (1.830)	-0.029 (1.118)	0.2216 (1.156)	1.363 (1.171)	1.484 (1.226)	1.010 (1.318)
Average IMR				-2.681** (0.462)		-0.356 (1.612)
Average calories				0.009 (0.066)		0.070 (0.136)
Average protein				1.207 (2.086)		0.199 (4.984)
Time			0.003 (0.004)	-0.054** (0.010)		
Country specific time trends	no	no	no	no	yes	yes
Country fixed effects	no	yes	yes	yes	yes	yes
R2	0.047	0.977	0.977	0.980	0.986	0.986
N	749	749	749	726	749	726

Based on data from 39 countries. Weighted least squares where weights are sample size used in calculation of average cohort height. Significance level indicated as *(5%), **(1%).

Table 8

Relationship between Infant Mortality Rate and Nutrition in Birth Year Dependent Variable: log infant mortality rate

	1	2	3	4
Constant	1.280 ^{**} (0.061)	1.353 ^{**} (0.072)	1.268 ^{**} (0.037)	0.919 ^{**} (0.037)
Energy consumption per capita (calories/100)	-0.075 ^{**} (0.004)	-0.083 ^{**} (0.006)	-0.019 ^{**} (0.003)	-0.005 [*] (0.002)
Protein consumption per capita (grams/100)	0.788 ^{**} (0.124)	1.117 ^{**} (0.209)	-0.220 [*] (0.110)	0.104 (0.076)
Time			-0.018 ^{**} (0.0002)	
Country specific time trends	no	no	no	yes
Country fixed effects	no	yes	yes	yes
R²	0.226	0.709	0.922	0.984
N	1442	1442	1442	1442

Based on data from 39 countries. Ordinary least squares. Significance level indicated as ^{*}(5%), ^{**}(1%).