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Child Nutrition and Economic Development

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CHILD NUTRITION AND ECONOMIC DEVELOPMENT

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Children's nutrition is both cause and consequence of broader health conditions, household income and living standards. This chapter describes the principal changes in child nutrition that have been associated with economic development across countries in recent decades, summarizing newly available data on anthropometric status, breastfeeding and food consumption as well as other influences on nutritional balances such as sanitation and disease prevention. Some of these changes are mediated by national or community-level policies and programs as well as medical interventions described elsewhere in this text, but most of the patterns described in this chapter occur autonomously as individuals respond to changing circumstances associated with economic development. These changes often occur slowly, without the conscious knowledge of those involved, and have only recently been documented thanks to the accumulation of evidence from a wide range of social environments.

IMPROVEMENTS OVER TIME AND COMPARISONS ACROSS COUNTRIES

Leo Tolstoy's classic novel *Anna Karenina* begins "All happy families are alike; each unhappy family is unhappy in its own way." This claim starts an epic, questioning search for whatever it might be that successes have in common. For economic development, a large social science literature documents wide variation in peoples' living conditions. These circumstances have often stagnated for centuries, with almost all people experiencing relatively poor health, low income and less preferred living standards, until new opportunities and forms of social organization trigger the onset of sustained improvement.¹ Rising income is eventually associated with large gains in adult height, weight, and many measures of health² and even measureable increases in subjective well-being.³ It turns out that success in one dimension is typically accompanied by successes in other areas. Many different obstacles might slow development, but successful societies often move in similar directions as people gradually achieve similar objectives.

In this chapter we focus on changing child nutrition, which is among the most universal human goals that economic development can help people pursue.^{4,5} We describe how child nutrition alters during economic development, defined very broadly to mean households' overall purchasing power over real goods and services. Households vary in how they acquire that purchasing power, which comes from labor earnings, home production and wealth of all kinds. Household purchasing power is measured as the sum of all income sources, adjusted for local prices in each year. For this calculation we use the Penn World Tables (PWT), which offers the world's broadest and most complete set of real income data, updated regularly by the Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania. We use PWT version 7.1, based on national accounts and price data from 146 countries between 1950 and 2010.⁶

Many aspects of child nutrition are likely to change as their families acquire more purchasing power; here, we focus only on what is most widely measured. Surveys of several million children from more than a hundred countries over multiple decades allow us to look systematically at changes in child height, stunting and wasting, as well as various contributors to nutritional status including food availability and diet quality, sanitation and water supplies,

breastfeeding behavior and treatment of childhood diarrhea, vaccination and vitamin A supplementation. Each of these measures reflects a different aspect of child nutrition that is discussed only briefly here, and analyzed at greater length in other chapters.

To describe changes during economic development, we compare the various child nutrition indicators to average real income per person in each country, at the time of observation. National income is an aggregate measure of all economic activity, but structural changes within society also matter. We end the chapter with a discussion of two structural changes that are particularly important for child nutrition: agricultural transformation (a shift from food production to other enterprises) and demographic transition (a shift from large to small families). These are closely related to each other and to average national income, and to a multitude of other social and institutional changes in gender relations, education and child care practices.

Our focus in this chapter is on changes over long periods and differences among very diverse countries, using national averages and prevalence rates as indicators of how populations differ from each other. Variation within a given country is itself of interest but is addressed primarily elsewhere. The one distributional issue of great concern here is the fraction of children in the country who fall below a clinical threshold of severe malnutrition. The economic-development counterpart of this is the fraction of households who fall below a poverty line. A long literature in economics concerns how increases in average income affect the prevalence of poverty, and the same methods have now been applied to changes in malnutrition.⁷

Many factors other than economic development clearly matter for child nutrition. Ethnographic studies describe in detail how children are raised, finding that social norms and beliefs can lead to a variety of choices regarding complementary feeding and other nutritional practices.^{8,9} These norms may eventually adjust to income changes, or may introduce variation that is unrelated to economic circumstances. Either way, by assembling data from millions of children around the world, we can look over a wide enough range of circumstances to see patterns that would otherwise be hidden. This chapter is descriptive, aimed at revealing stylized facts about long-term relationships. Once those facts are known, other techniques would be needed to address causality. In particular, for this chapter we are looking at contemporaneous correlation, recognizing that this misses the time delays that play a major role in any underlying causal mechanisms.¹⁰

For visual clarity, our description of the evidence uses scatter plots and regression lines of each child nutrition indicator against the natural log of real income. This approach transforms exponential relationships into linear ones, and allows us to span the full range of purchasing power which varies from US\$180 per person per year (a log value of 5.2) in Liberia and the Democratic Republic of Congo during their years of civil war, to above US\$60,000 (a log value of 11) in Qatar and the United Arab Emirates during their years of highest oil revenue. The regression line traces the average change in each nutrition indicator associated with a constant one percent change in purchasing power, while the scatter of individual observations reveals the pattern of variation around that central tendency. Systematic nonlinearities are often visible, for example if observations cluster below or above particular parts of the regression line, and the overall variance or precision is shown by a 95 percent confidence interval around the

regression's estimated mean at each income level. The resulting figures reveal long-term, cross-country patterns that could not be seen within individual countries or shorter time periods.

ANTHROPOMETRIC FINDINGS AND ECONOMIC DEVELOPMENT:

CHILD HEIGHT, STUNTING AND WASTING

Until very recently, the anthropometric data used to study nutrition in economic history referred mainly to adolescents and adults, whose heights were often measured for military or other institutional purposes.² Only since the 1990s have large-scale anthropometric surveys of children in developing countries obtained sufficient sample sizes to identify variation in the first years of life. Among the first striking results was that the growth faltering associated with undernutrition actually occurs very early in infancy and early childhood, mostly prior to age two.¹¹ The most widely reported data typically refer to children from birth to age 5, and have been assembled from the pioneering Demographic and Health Surveys (DHS) funded by USAID, as well as the Multiple Indicator Cluster Surveys (MICS) of UNICEF and other sources.

We begin our description of the data with the broadest possible coverage of countries and years, using estimates provided by the Nutrition Impact Model Study (NIMS).¹² They compute nationally-representative height and weight distributions for children under 5 across 141 developing countries, interpolating between surveys for annual data from 1985 through 2011 to measure progress over time.¹³ Here, we extend their analysis to correlations with income, by combining these estimates with the PWT 7.1 measure of each country's real purchasing power. We begin with average heights, then consider the prevalence of stunting and wasting using the smaller sample size of actual surveys starting in 1966 from the WHO Global Database on Child Growth and Malnutrition.¹⁴

For each anthropometric measure, we show a scatter plot of each observation against the log of real income per person. The observations are drawn in two different shadings, one for the most recent decade (2000-2010) and one for earlier years, with separate regression lines that show a 95 percent confidence interval. This presentation is in the tradition of Samuel Preston, who used a somewhat similar diagram to show how life expectancy at each income level changed over successive decades.¹⁵ A shift in such Preston curves would be associated with variables other than contemporaneous income, and could include the cumulative effect of past income, new technologies or changes policies and institutions.

Figure 1 shows the correlation between average real income per person and average child height, for the 137 countries that are in both the NIMS and PWT datasets, from 1985 (when NIMS data begin) to 2010 (when PWT data end). We have a total of 3,485 country-year observations, based on underlying data from over 7.7 million survey subjects.¹³ On this scatter plot, a few outlier countries can be seen trending over time. For example, the series of observations that crosses the -2 line at a log income level of about 9 is Guatemala, a country with famously poor nutrition outcomes given its income level.¹⁶ This chart reveals that Guatemala has recently been converging towards the levels achieved elsewhere, as both income and height have risen sharply and moved closer to the regression line.

The regression lines in Figure 1 suggests that a very poor country with a log income around 6 (US\$400 per person, per year) can be expected to have a mean height-for-age z score around -2.

In other words, their average child would be shorter than 97.5 percent of children in the WHO's global reference population. At the highest income levels in this sample (Qatar and UAE), the average child is still shorter than the WHO reference median, which could be because this sample includes only "developing" countries, all of whom had relatively low incomes in the recent past. Comparing the two regression lines, average child heights at each income level are significantly higher in the most recent decade than in previous years. This could be due to a cumulative lagged effect of income itself, or to omitted variables that improve over time, such as innovations in health care, improved access to medical care, child health norms, and nutritional innovations of all kinds.

Figure 2 shows the prevalence of stunting, as the fraction of children with HAZ scores below -2. The regression line shows that at the world's lowest income levels, roughly half of children can be expected to be stunted. As with Figure 1, the scatter plot shows a clear association and also an improvement over time in the position of the regression line: at low income levels, fewer children were stunted in the 2000s than in previous decades. Like Figure 1, the regression lines converge and are not significantly different from each other at high income levels. Also, nonlinearity in the scatter plot data is readily apparent in these data, as the richest of these developing countries have brought their stunting rates down close to the level seen in the WHO's reference population itself. Curvature of the scatter plots around the linear regression line is consistent with the result found elsewhere that a given percentage increase in income is most powerful in reducing malnutrition in poor countries with widespread undernutrition, while similar improvements in countries that have already made progress would require more targeted programs.⁷

The height-for-age data shown in Figures 1 and 2 are constructed by the NIMS project, imputing values for the countries and years without survey data.¹³ If we limit the picture to actual surveys that are in the WHO's Global Database on Child Growth and Malnutrition,¹⁴ we have a smaller sample size but broader coverage, since we can include a few observations made earlier in time and in industrialized countries. Figures 3 and 4 use the actual surveys compiled by the WHO to show both stunting and wasting prevalence. Looking first at stunting, Figure 3 confirms the result found in Figure 2. The regression lines have similar slope and somewhat wider confidence intervals due a smaller sample size, and yet confirm that there was a significant improvement over time, with less stunting in poor countries for their income level. Figure 4 shows the prevalence of wasting, defined as weight for height z scores below -2. This also has a strong association with income, with the average very poor country having a prevalence rate above 10 percent, but many countries near the lower bound for this type of malnutrition.

Overall, the anthropometric evidence shows a clear positive association between income and child nutritional status, with additional improvement in the 2000s relative to previous decades. This applies both to the prevalence of extreme undernutrition below a z score of -2 as shown in Figures 2, 3 and 4, and also to national average child heights as shown in Figure 1. These changes in stunting, wasting, and average stature convey different kinds of information. Prevalence rates of extreme conditions are particularly important for targeting interventions to the most needy, while changes in means or medians provide more sensitive measures of population-wide changes.¹⁷

FOOD AVAILABILITY:

DIET QUALITY AND DIETARY ENERGY

Child nutrition is not merely a matter of anthropometrics. Dietary patterns are important for many other reasons, including health and activity levels as well as cultural values. Figure 5 shows the major changes in food availability associated with per capita income, distinguishing between one aspect of diet quality (on the left axis) and total energy availability (on the right). The data shown in Figure 5 refer to a country's national average family diet. Direct surveys of what children eat have not yet had sufficient precision, over a large enough sample size and range of incomes, to capture the economic-development effects described in this chapter. In fact, even the national-average data shown here are estimates computed by FAO staff from other observations, using an accounting approach to balance consumption against total production, waste and seed use, international trade and stock changes. These "Food Balance Sheets" infer the national-average diet from other more readily observed flows in food markets.¹⁸

The energy availability shown in Figure 5 includes all kind of calories. A corresponding measure of food quality could be computed in various dimensions, such as dietary diversity (e.g. the number of distinct types of food consumed on a given day) or food security (e.g. the fraction of time in which households are unable to access needed foods). Here we introduce the simplest and most direct possible measure of dietary composition, namely the fraction of calories that are derived from animal sources including dairy, eggs, and fish as well as animal meats.

Figure 5 illustrates how many of the world's poorest countries have a nearly vegan diet, while higher income countries get 20 percent or more of their total calories from animal sources. Various kinds of anthropological and contemporary evidence suggests that availability of these foods at the low levels of consumption observed historically and in today's low-income countries could play a causal role in stature,¹⁹ although that association could also be due to reverse causality, if people who are better nourished and also have higher incomes prefer more animal-sourced foods for taste or other reasons.

DISEASE EXPOSURE AND TREATMENT:

SANITATION AND WATER SUPPLIES, BREASTFEEDING AND DIARRHEA TREATMENT

Nutritional status depends on the balance between intake and needs, which in turn depends on disease exposure and treatment. Figures 6 and 7 illustrate some key dimensions of how these factors change during economic development, using datasets assembled by WHO, UNICEF, and the DHS.¹⁴

Figure 6 shows the inter-related issues of access to sanitation and access to improved water sources, compiled by the WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply and Sanitation. These issues are described in more detail in Chapter 42 of this text; for our data, access to sanitation is defined as households using any kind of improved facility such as a protected pit latrine or composting toilet as well as flush toilets, piped sewage and septic tanks, as opposed to open pits, buckets, hanging toilets or flat land. Access to improved water is defined as any improved source such as protected wells and springs as well as piped water sources, as opposed to open springs, wells, and tanks or surface water. As shown by the two scatter plots and regression lines, in the poorest countries under 20 percent of the population has

access to sanitation, while around 50 percent has access to improved water supplies, and both converge to near 100 percent at higher income levels. The improvement in sanitation is clearly one of the most dramatic changes in children's nutrition-related environment, being closely associated with diseases discussed elsewhere in this volume including environmental enteropathy.²⁰

Figure 7 addresses two other, very different aspects of nutrition-related disease exposure and treatment, namely the fraction of infants under 6 months who are exclusively breastfed (as opposed to other drinks or solid food), and the fraction of children under 5 for whom diarrhea is treated with oral rehydration and continued feeding (as opposed to suspension of feeding, or other liquids). These appear to have almost no significant correlation with real income across the countries surveyed. The fact that higher income people do not pursue these practices more often does not imply that they are undesirable. Richer people may be able to afford more breastmilk substitutes and have less exposure to diarrheal diseases, or may be surveyed differently regarding these practices.

VACCINATION AND SUPPLEMENTATION: IMMUNIZATION AND VITAMIN A CAMPAIGNS

The data presented so far are the aggregate result of decentralized decisions taken by individual households. None of the variables shown in Figures 1-7 are directly controlled by government or philanthropic agencies, although these organizations' policies, programs and interventions do have some influence on individual household behavior. Centralized agencies are relatively more important for the vaccination and supplementation campaigns presented in Figures 8 and 9, which are typically undertaken on a regional scale by a small number of organizations, to supplement whatever households can do for themselves. Figure 8 shows coverage data for vaccination against tuberculosis (BCG) and against diphtheria, pertussis and tetanus (DPT) among children surveyed between their first and second birthdays, and Figure 9 shows coverage of measles vaccination and vitamin A supplementation. Vaccination data are from WHO and UNICEF, while vitamin supplementation data are from UNICEF.¹⁴

The vertical axes in Figures 8 and 9 shows the proportion of children receiving vaccination and supplementation, so the scaling of these scatter plots and regression lines is directly comparable to the population shares shown in Figures 6 and 7. Visual comparison reveals that vaccination coverage (on Figures 8 and 9) has wider variation at each income level, and less steep increase at higher incomes, than household access to improved sanitation (on Figure 6). One reason could be that vaccination requires less investment by households themselves, and so can more readily be provided in low-income settings. Vitamin A supplementation coverage (on Figure 9) is like diarrhea treatment in its relation to economic development, with very wide variation at each income level and less use at higher incomes. Supplementation may be less widely needed at higher incomes, or less likely to attract the support of public and philanthropic agencies.

STRUCTURAL CHANGES AFFECTING CHILD NUTRITION: AGRICULTURAL TRANSFORMATION AND DEMOGRAPHIC TRANSITION

The figures presented above describe how various dimensions of child nutrition vary with the growth of national income, showing strong trends as well as variation across countries and over time. Two other important influences on child nutrition during economic development involve

structural change within society: the agricultural transformation from farming to other occupations, and the demographic transition from short to long life expectancy. These changes are described in detail elsewhere,²¹ and are briefly summarized here in respect to their influence on child nutrition.

Agricultural transformation is a shift in employment and expenditure from food to other enterprises. In the world's poorest societies, most people have no choice but to live in rural areas, relying on natural resources and household labor to obtain food, fuel and water. If opportunities arise to improve productivity, either within agriculture or in other activities, then people can save and invest, specialize and trade, ultimately moving from into a wide array of services and manufacturing. This transformation occurs within rural areas, and also allows migration to towns and cities which sustains further economic development. The transformation out of agriculture as incomes rise explains why the poorest people and most malnourished children are typically found in the most agriculturally-oriented places, both across and within countries. Because of agricultural transformation, the apparent paradox in economic development that food production is associated with being malnourished can typically be resolved by controlling for real income.

Demographic transition is another kind of structural change with surprising implications for child nutrition. This familiar shift towards longer life and then also lower fertility almost always starts with lower child mortality, often associated with an improvement in nutrition. That can lead quickly to a decline in birth rates, particularly if accompanied by opportunities for education, women's employment and access to contraception, but in the meantime there is a burst of population growth and a demographic burden of more children per household. The rise in child dependency during the demographic transition helps explain why child malnutrition often worsens over time, before it improves. The demographic burden of child care falls disproportionately on young women, until declining fertility rates help the age structure swing back towards more working-age adults per child. The eventual rise in the workforce as a fraction of the population then offers a demographic gift that can fuel rapid economic development, particularly when combined with agricultural transformation and off-farm employment growth.

Demographic transition interacts with agricultural transformation in a way that often makes nutrition improvement harder in low-income countries, and then easier at higher income levels. In poor countries, the non-agricultural sector is initially so small that even very rapid rates of off-farm employment growth cannot absorb all of the increasing number of working-age people. Despite successful year-to-year economic development and rapid urbanization, there will be a rising number of workers who have no choice but to farm, typically with less and less land and other natural resources per worker. That burden of declining land area per farmer in poor countries can be offset only by raising their crop yields, until the size of their country's non-agricultural sector has become large enough its annual growth to absorb each year's increase in the adult workforce.

In summary, these two structural changes associated with economic development impose temporary burdens on child nutrition in low-income countries. By the arithmetic of year-to-year change, they serve to raise the number of children per adult and lower the area of land per farmer in the early stages of structural change, making progress harder before it gets easier. At later stages of economic development, child dependency rates and area per farmer can increase, both

of which help the poorest and most malnourished escape more quickly from poverty. The development process may start earlier or later, varies widely in speed and occasionally stalls altogether. But to the extent that economic development proceeds, it is characterized by remarkable similarities that help explain the patterns we see across countries and over time. In that sense, successful societies are alike even as their progress towards that shared destination involves a variety of diverse forces.

CONCLUSIONS

This chapter describes changes in child nutrition that have been associated with economic development over several decades in more than 100 countries. We use data recently assembled from millions of children to compare changes in purchasing power with observed child height, stunting and wasting, as well as various contributors to nutritional status including food availability and diet quality, sanitation and water supplies, breastfeeding behavior and treatment of childhood diarrhea, vaccination and vitamin A supplementation. Each aspect of child nutrition has wide variation across countries, but some are closely linked to national income.

The most notable links between nutrition and income are for child height and stunting, both of which improve sharply with economic development especially among the poorest countries. We also find strong links for access to sanitation and diet quality, as measured here by the fraction of calories obtained from animal products. Total food availability, as measured by total calories per person, and access to improved water as well as child vaccination rates are also associated with higher income, although vaccination rates have wide variance across countries at each income level.

Nutrition practices that have almost no correlation with income across the available data are the rates at which children are exclusively breastfed, or are treated for diarrhea with oral rehydration and continued feeding. Vitamin A supplementation rates are actually lower in more developed countries. These low or negative correlations with income could be due to diminished need for these practices as income rises, or to a lack of public support in richer countries, or perhaps to less frequent observation even when they are practiced.

The links between child nutrition and economic development described in this chapter are accompanied by very large changes within countries, including the agricultural transformation from a focus on food production to more other activities, and the demographic transition from large to small families. Together these impose headwinds against nutrition improvements in low-income countries that help explain the cross-country patterns we see, and make success in those settings all the more remarkable. The extraordinary gains in nutrition associated with economic development are driven by deep social and institutional changes involving gender relations, educational and child care practices as well as medical and nutritional innovations described elsewhere in this volume, all of which offer opportunities for health practitioners and policy officials to achieve even greater improvements in the future.

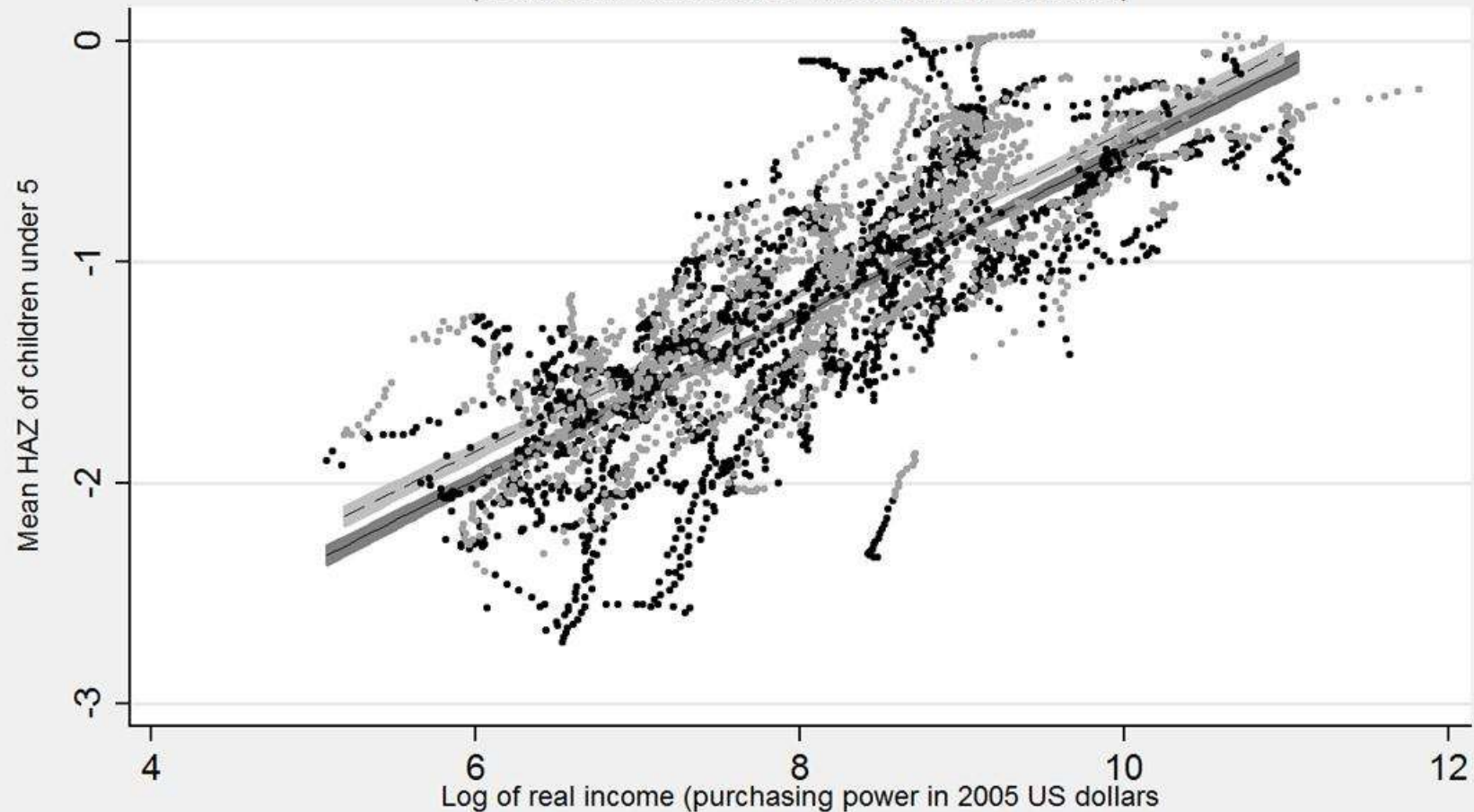
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Figure 1. Child height and real income, 1985-99 and 2000-10

(Ezzati et al. estimates, N=3,485 from 137 countries)

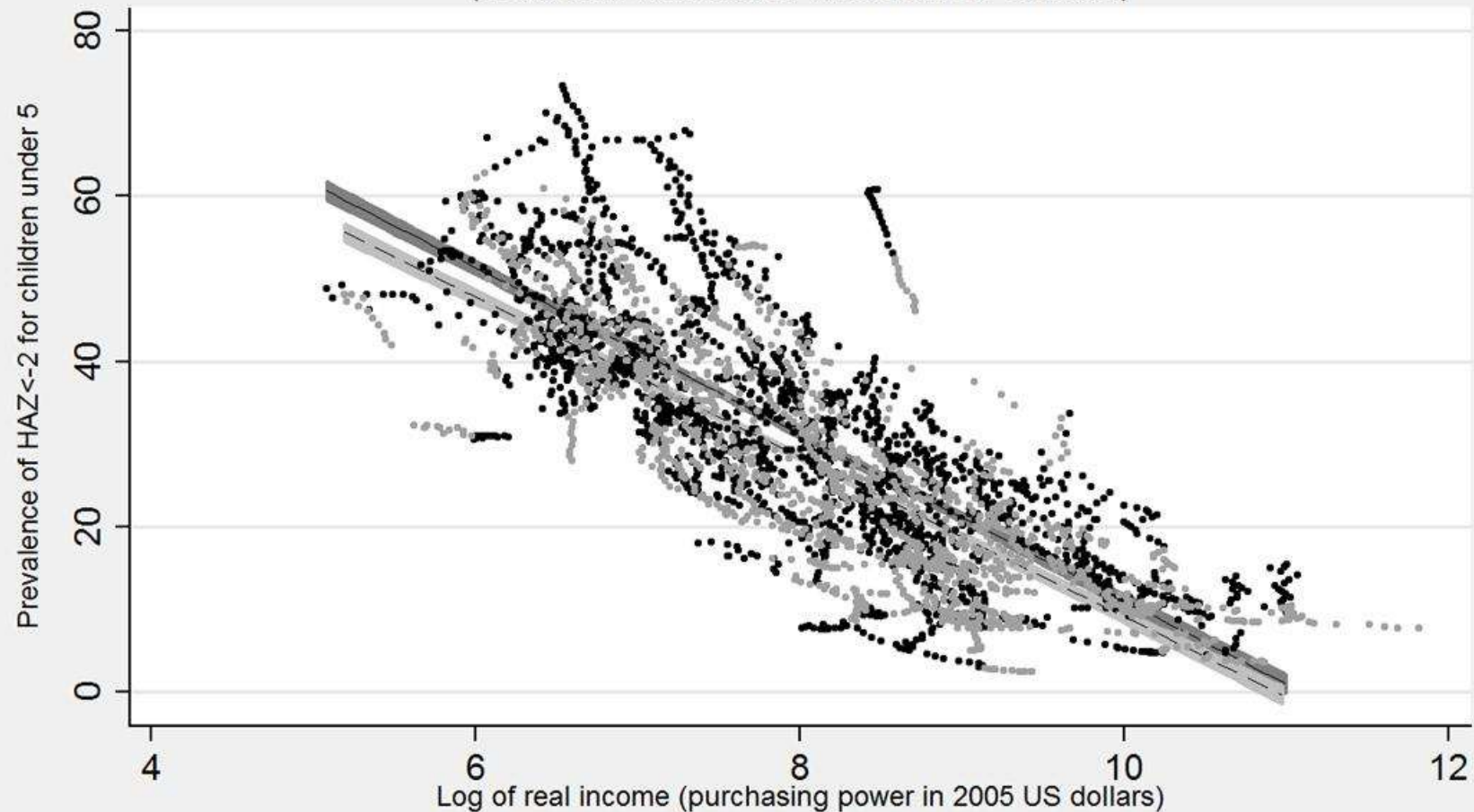


Note: Data shown are for 1985-99 (darker shading) and 2000-2010 (lighter shading), with 95% confidence intervals around linear regressions. Sample sizes are N=1,978 across 137 countries for 1985-1999 and N=1,507 across 138 countries for 2000-2010.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Height estimates are courtesy of Prof. Majid Ezzati, as detailed in G.A. Stevens et al. (2012), *The Lancet* 9844: 824-834, downloaded 30 Dec. 2012 from www1.imperial.ac.uk/publichealth/departments/ebs/projects/eresh/majidezzati.

Figure 2. Prevalence of stunting and real income, 1985-99 and 2000-10

(Ezzati et al. estimates, N=3,485 from 137 countries)

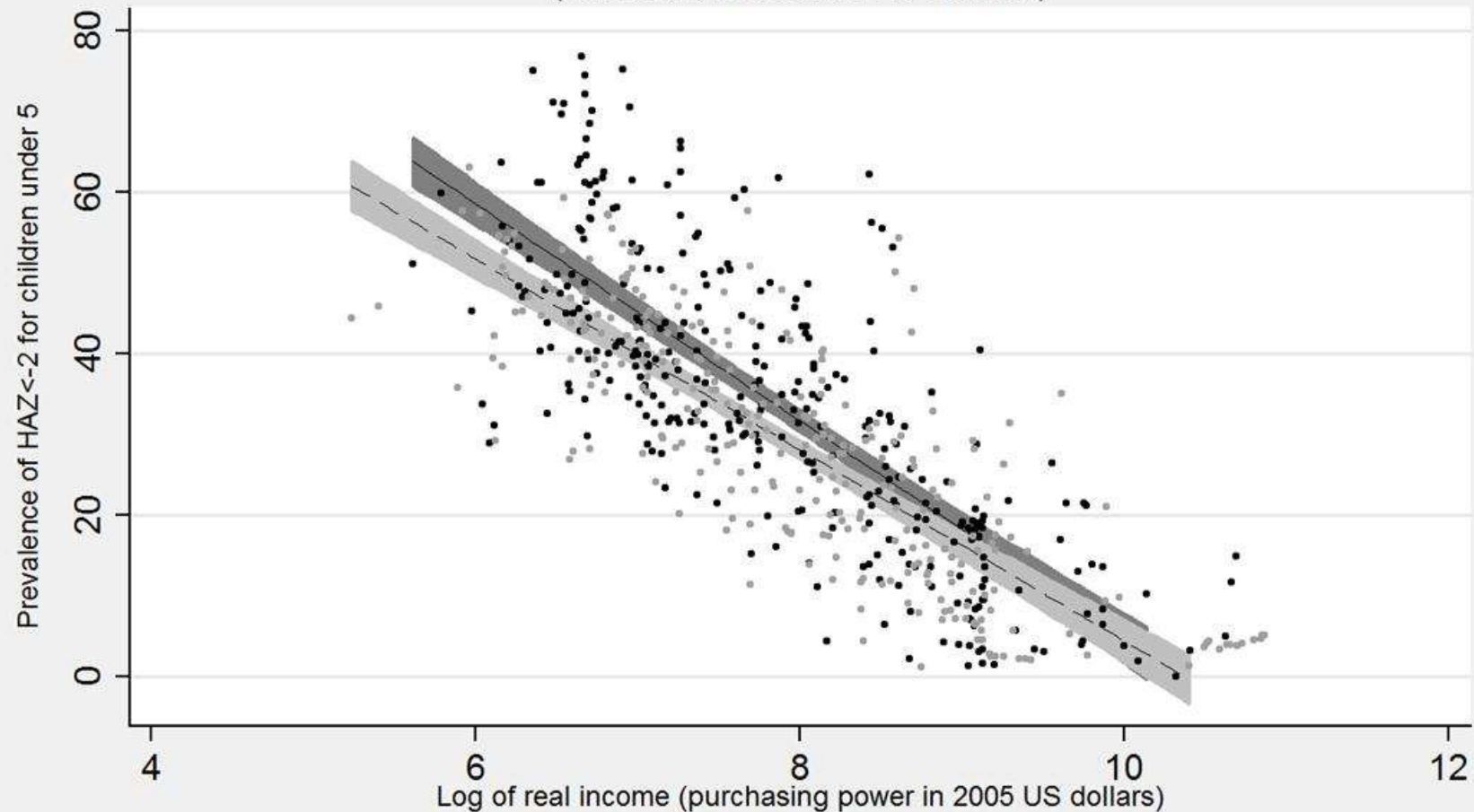


Note: Data shown are for 1985-99 (darker shading) and 2000-2010 (lighter shading), with 95% confidence intervals around linear regressions. Sample sizes are N=1,978 across 137 countries for 1985-1999 and N=1,507 across 137 countries for 2000-2010.

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Figure 3. Prevalence of stunting and real income, 1966-99 and 2000-10

(WHO data, N=608 from 146 countries)

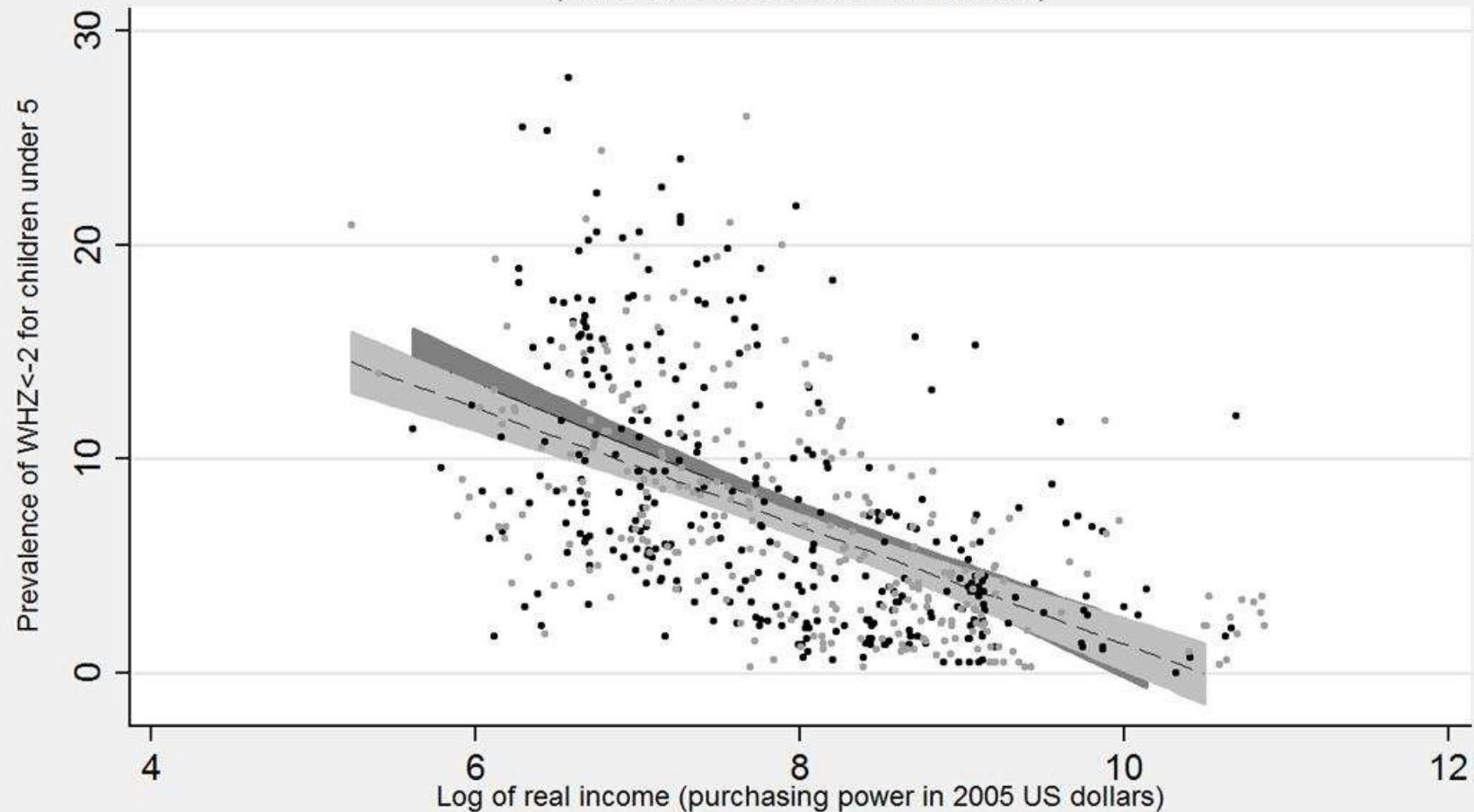


Note: Data shown are for 1966-99 (darker shading) and 2000-2010 (lighter shading), with 95% confidence intervals around linear regressions. Sample sizes are N=320 across 128 countries for 1966-1999 and N=288 across 127 countries for 2000-2010.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Stunting data are from WHO, Global Database on Child Growth and Malnutrition, downloaded 30 Dec. 2012 from World Bank, Health Nutrition and Population Statistics (<http://databank.worldbank.org>).

Figure 4. Prevalence of wasting and real income, 1966-99 and 2000-10

(WHO data, N=601 from 146 countries)

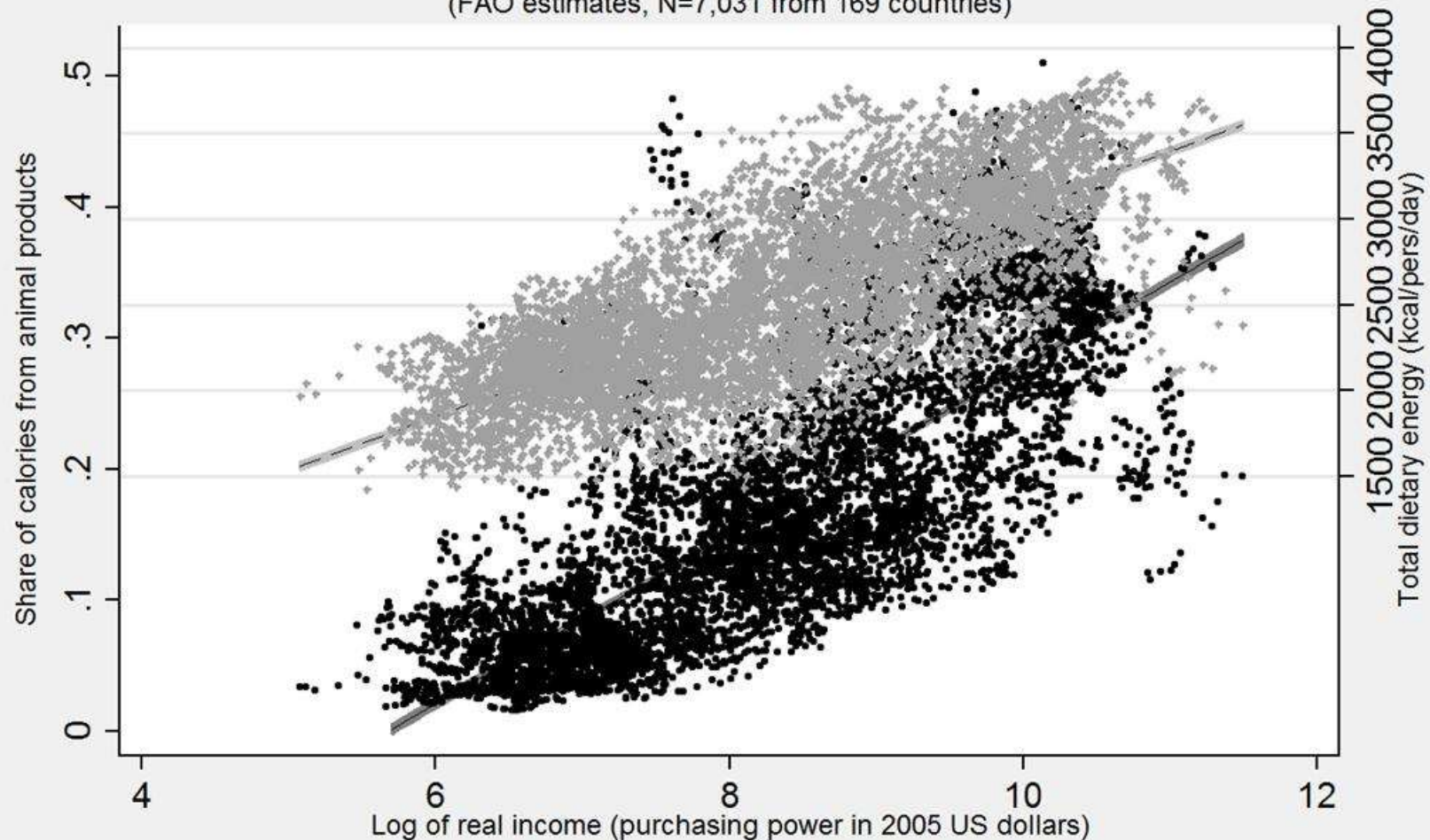


Note: Data shown are for 1966-99 (darker shading) and 2000-2010 (lighter shading), with 95% confidence intervals around linear regressions. Sample sizes are N=316 across 127 countries for 1966-1999 and N=285 across 126 countries for 2000-2010.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Stunting data are from WHO, Global Database on Child Growth and Malnutrition, downloaded 30 Dec. 2012 from World Bank, Health Nutrition and Population Statistics (<http://databank.worldbank.org>).

Figure 5. Food supply and real income, 1961-2009

(FAO estimates, N=7,031 from 169 countries)

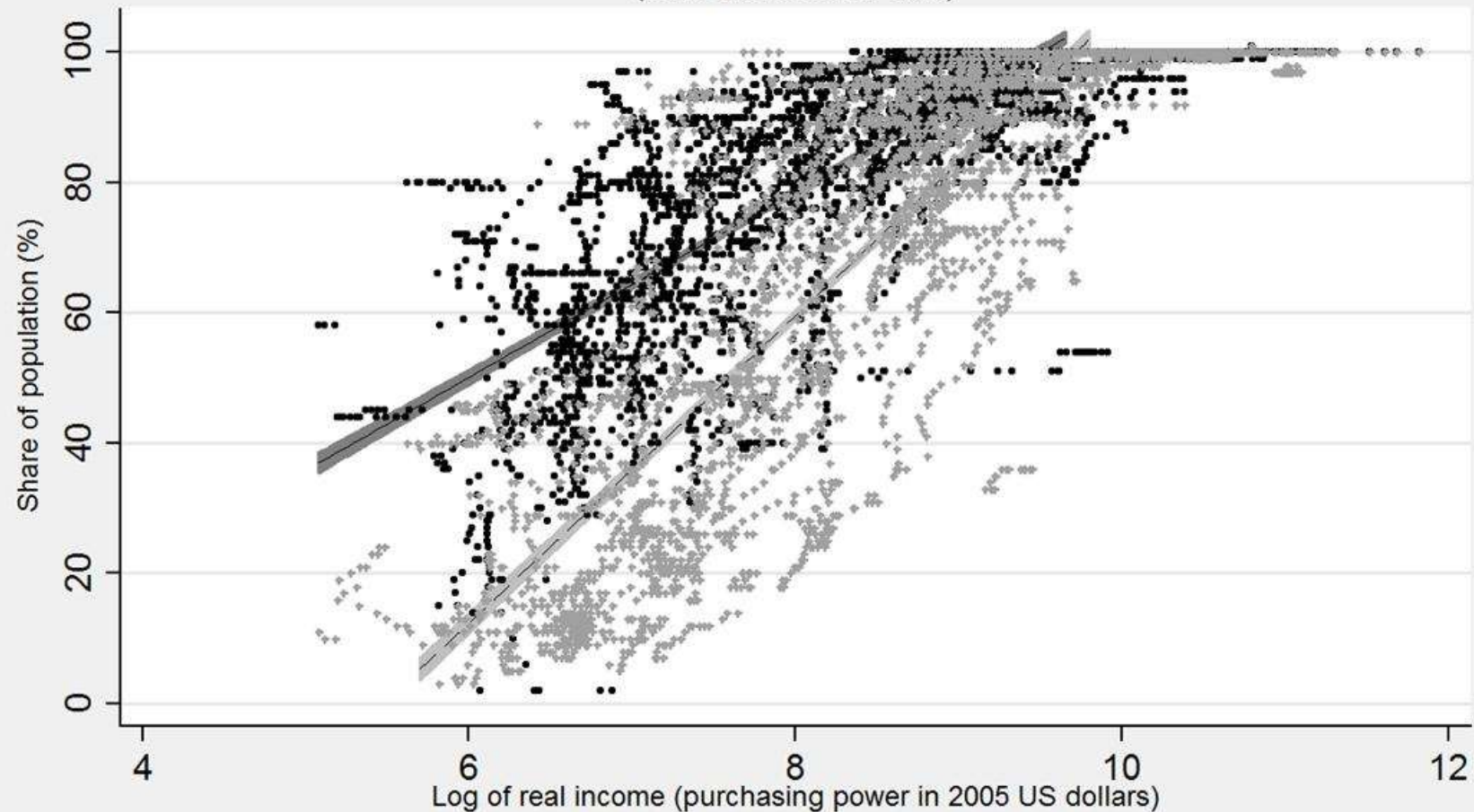


Note: Animal product share is shown in darker shading on the left scale; total energy is shown in lighter shading on the right (higher) scale. Both variables have the same sample size, and linear regression lines with 95% confidence intervals.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Food supply data are Food Balance Sheet estimates, downloaded 30 Dec. 2012 from <http://faostat3.fao.org>.

Figure 6. Access to sanitation, improved water supplies and real income, 1990-2010

(WHO and UNICEF data)

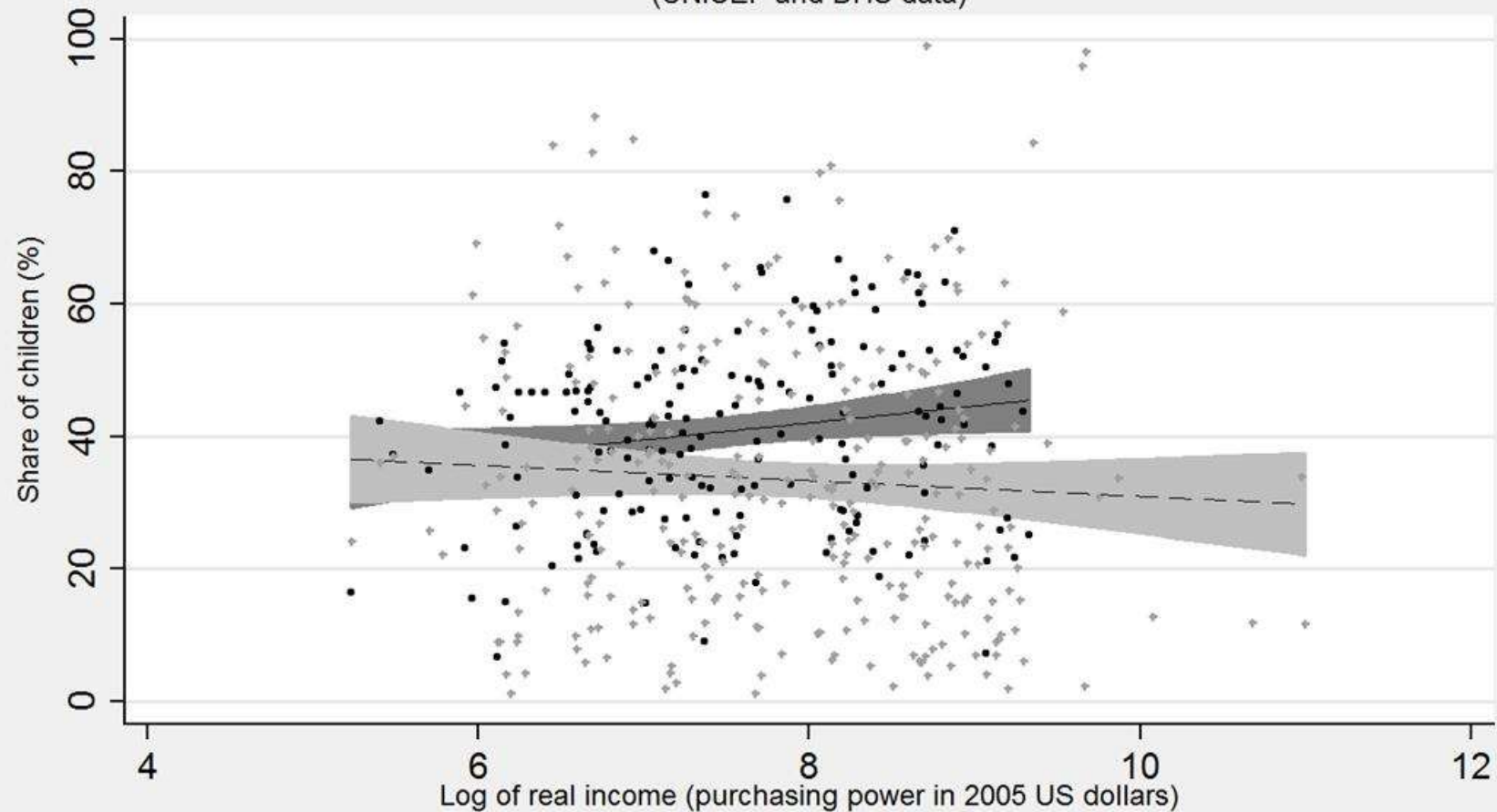


Note: Access to improved water (N=3,556 from 178 countries) is shown in darker shading; access to sanitation (N=3,485 from 176 countries) is shown in lighter shading. Both variables have linear regression lines showing 95% confidence intervals.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Water and sanitation data are from WHO and UNICEF Joint Measurement Programme, downloaded 30 Dec. 2012 from World Bank, Health Nutrition and Population Statistics (<http://databank.worldbank.org>).

Figure 7. Exclusive breastfeeding, diarrhea treatment and real income, 1990-2010

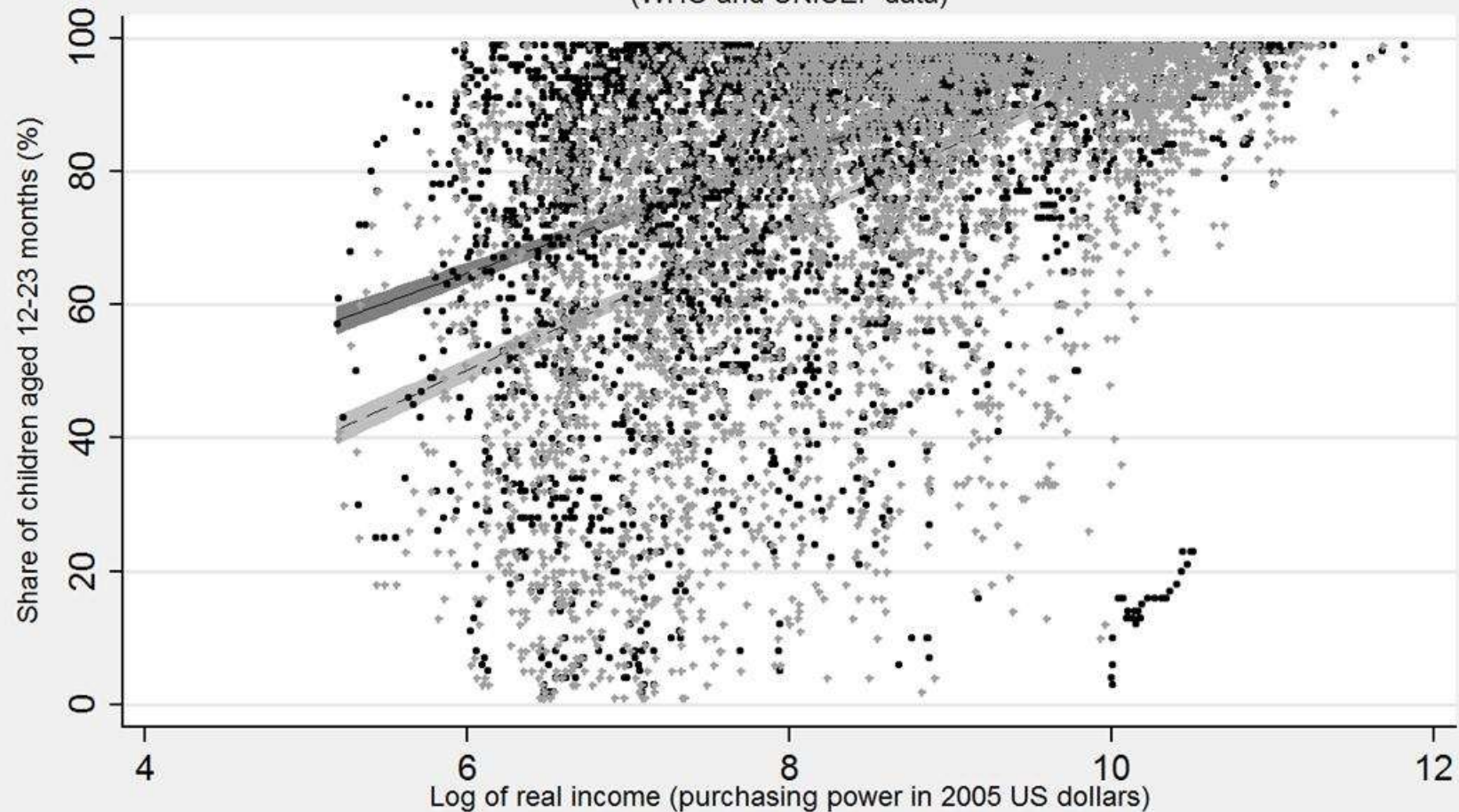
(UNICEF and DHS data)



Note: Treatment of diarrhea (% of children under 5 receiving oral rehydration and continued feeding) is shown in darker shading, with N=174 from 96 countries. Exclusive breastfeeding (% of children under 6 months) is shown in lighter shading, with N=297 from 134 countries). Both variables have linear regression lines with 95% confidence intervals.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Breastfeeding and diarrhea treatment data are from UNICEF and the Demographic and Health Surveys (DHS) by Macro International, downloaded 30 Dec. 2012 from World Bank, Health Nutrition and Population Statistics (<http://databank.worldbank.org>).

Figure 8. BCG and DPT vaccination rates and real income, 1980-2010
(WHO and UNICEF data)

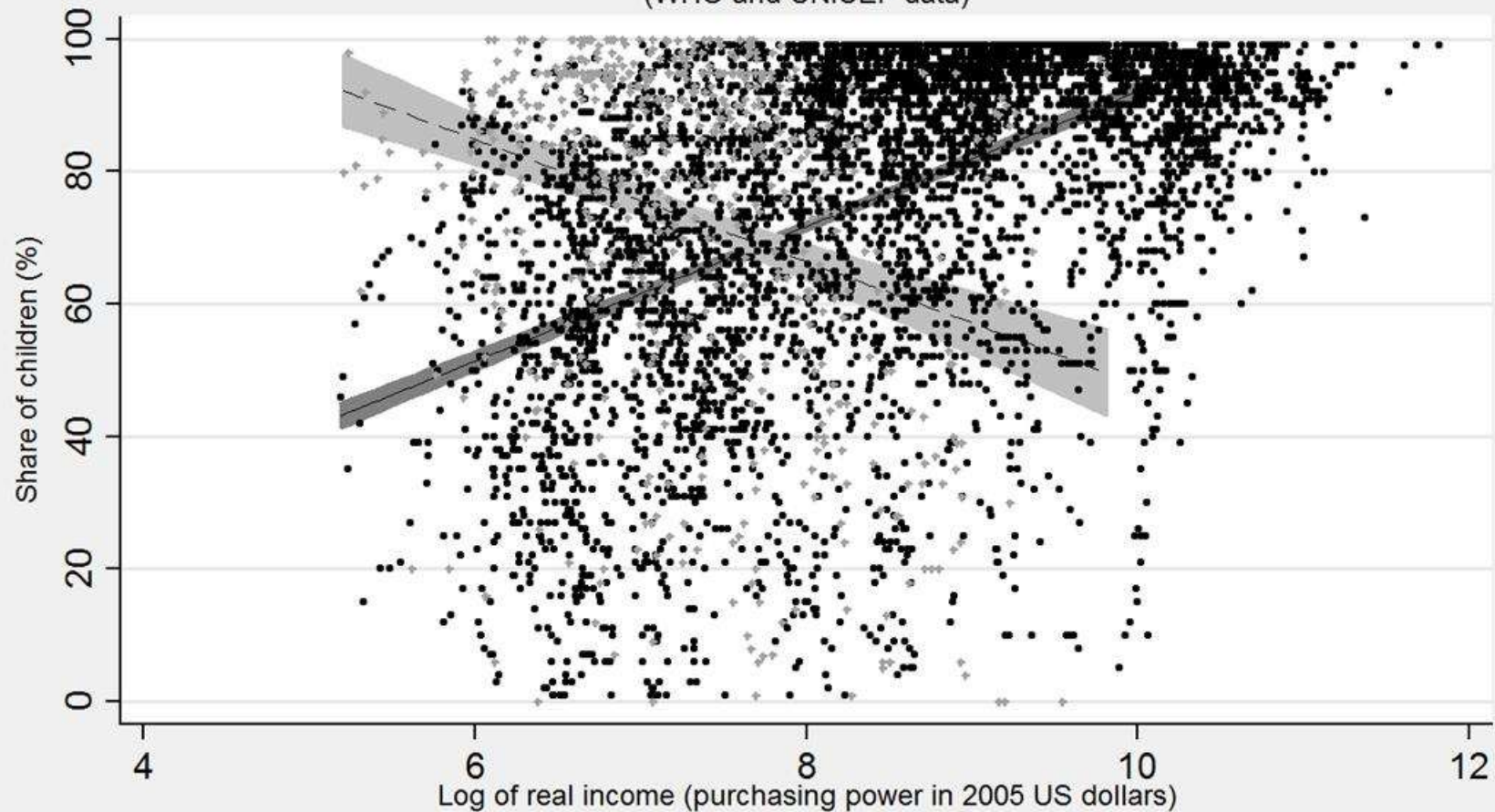


Note: BCG vaccination against tuberculosis (% of children, single dose) is shown in darker shading, with N=4,208 from 158 countries.
DPT vaccination against diphtheria, pertussis, and tetanus (% of children, 3 doses) is in lighter shading, with N=5,096 from 183 countries.
Both variables have linear regression lines with 95% confidence intervals.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Vaccination is from WHO and UNICEF, downloaded 30 Dec. 2012 from World Bank, Health Nutrition and Population Statistics (<http://databank.worldbank.org>).

Fig. 9. Measles vaccination, vitamin A supplementation and real income, 1980-2010

(WHO and UNICEF data)



Note: Measles vaccination (% of children aged 12-23 months, single dose) is shown in darker shading, with N=5,005 from 183 countries. Vitamin A supplementation (% of children aged 6-59 months, at least one capsule in the 6 months before survey) is shown in lighter shading, with N=602 from 86 countries. Both variables have linear regression lines with 95% confidence intervals.

Source: Author's calculation. Income data are from Penn World Table Version 7.1 (Nov. 2012), online at <https://pwt.sas.upenn.edu>. Vitamin A data begin in 1999 and are from UNICEF. Vaccination data are from WHO and UNICEF, downloaded 30 Dec. 2012 from World Bank, Health Nutrition and Population Statistics (<http://databank.worldbank.org>).