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Reducing Child Undernutrition: Past Drivers and Priorities for the Post-MDG Era

LISA C. SMITH [a] and LAWRENCE HADDAD [b,*]
[a] *TANGO International, Inc., Tucson, Arizona, USA*
[b] *International Food Policy Research Institute, Washington, D.C., USA*

Summary. — As the post-MDG era approaches in 2016, reducing child undernutrition is gaining high priority on the international development agenda, both as a maker and marker of development. Revisiting Smith and Haddad (2000), we use data from 1970 to 2012 for 116 countries, finding that safe water access, sanitation, women's education, gender equality, and the quantity and quality of food available in countries have been key drivers of past reductions in stunting. Income growth and governance played essential facilitating roles. Complementary to nutrition-specific and nutrition-sensitive programs and policies, accelerating reductions in undernutrition in the future will require increased investment in these priority areas.

Key words — child undernutrition, underlying and basic determinants, South Asia, Sub-Saharan Africa, post-2015 development goals

1. INTRODUCTION

In 2011 undernutrition was estimated to be implicated in 45% of all deaths among children under five, some 3.1 million children worldwide (Black *et al.*, 2013). It has far-reaching, long-term effects on those who survive. Undernutrition in the first 1,000 days post conception represents a fundamental squandering of human potential. In these crucial days, the body is quickly laying down its fundamental building blocks for brain development and future growth. Any disturbance leaves a long-lasting mark: damage from undernutrition in early life is largely irreversible. The school performance of undernourished children is below potential. They have lower work capacity and productivity as adults. Later in life they have an increased likelihood of being overweight and developing associated chronic diseases such as cardiovascular disease, diabetes and cancer, and to suffer from mental health issues (Hoddinott *et al.*, 2013; Haddad, 2013a; World Bank, 2013a). When girl children suffer from undernutrition, their own children are more likely to suffer from it in their first 1,000 days post conception (UNSCN, 2010).

As one might expect, such personally damaging impacts of undernutrition for the world's youngest citizens and their families, along with its intergenerational transmission, have severe consequences for entire economies, dampening economic growth and poverty reduction. The development community is increasingly recognizing that slower-than-expected progress toward reaching the Millennium Development Goals (MDGs) by 2015—including those for poverty, secondary education, child mortality, and maternal health—is due, in large part, to lack of investment in children's nutrition (World Bank, 2013a).

Table 1 presents trends in stunting, a measure of chronic, long-term undernutrition, among children under five in the developing countries since the 1970s. Globally, great strides have been made over the last four decades. In 1970, over 50% of all developing-country children were stunted; by 2010 the prevalence had fallen to 30. However, prevalences and trends vary greatly across regions. In the 1970s the highest prevalences were found in South Asia, followed by East Asia and the Pacific. The highest prevalences by far are now in South Asia and Sub-Saharan Africa, where a full 40% of all children under five are stunted. Despite the progress that has been made, undernutrition remains unacceptably high, and the problem is far from solved.

The current momentum within developing countries and internationally to address the problem of child undernutrition has never been higher (*Lancet*, 2013). The rise of the Scaling Up Nutrition (SUN) movement, starting in 2010, and the publication of the *Lancet* Maternal and Child Nutrition Series in 2008 have both served to raise awareness of the extent and consequences of child undernutrition. Nutrition has consequently been greatly elevated on the global development agenda, and the global commitment to reducing undernutrition is stronger than ever (Gillespie *et al.*, 2013). A further marker of this commitment is the inclusion of "Food Security and Good Nutrition" (including indicators on child stunting and wasting) as one of 12 Development Goals proposed in the UN's High Level Panel on Development After 2015.

Given the above momentum, answers to the question of how to reduce undernutrition are in great demand. The recently released 2013 *Lancet* Maternal and Child Nutrition Series introduces a comprehensive Framework for Action, having three core components (*Lancet*, 2013):

(1) *Nutrition-specific* interventions that directly address the immediate causes of child undernutrition, that is, inadequate dietary intake and poor health status;
(2) *Nutrition-sensitive* interventions that incorporate nutrition goals and actions into interventions that address

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Table 1. *Trends in the prevalence of stunting among children under five in developing countries, 1970–2010*

Region	1970	1980	1990	2000	2010	Change 1970–2010	Percentage change b/
						(Percentage points)	
South Asia	68.8	66.6	61.3	49.7	40.0	−28.8	−41.9
Sub-Saharan Africa	46.1	44.2	47.2	43.8	40.0	−6.1	−13.2
East Asia and the Pacific	54.9	48.1	42.4	25.7	13.1	−41.8	−76.1
Middle East and North Africa	42.6	30.3	30.8	26.7	20.6	−22.0	−51.6
Latin America and the Caribbean	36.9	29.2	22.4	18.1	12.1	−24.8	−67.2
Europe and Central Asia	a/	a/	27.1	a/	12.1		
All developing countries	54.3	49.3	44.4	36.1	29.2	**−25.1**	−46.2

Notes: 1990 and 2010 regional estimates are from UNICEF/WHO/World Bank (2012), broken down by UNICEF region. Those for 2000 are estimated using country data from the main data set used for this paper's analysis (weighted with under-five population data from UNPD (2011)) with the exception of that for Latin America and the Caribbean, which is from de Onis *et al*. (2011). The overall developing-country prevalences for 1990, 2000 and 2010 are from de Onis *et al*. (2011). Prevalences for 1970 and 1980 are predicted using country-fixed effects regression and the underlying and basic determinants (excluding the governance indicators) employed in the main models of this paper as predictors.
a/ Under-five population coverage for the region is insufficient for calculating stunting estimates.
b/ Decline over 1970–2010 as a percent of 1970 level.

the underlying causes, which are: household food insecurity, poor quality of caring practices for mothers and children, and unhealthy living environments; and

(3) *Building an enabling environment* that addresses the basic causes, more distal factors related to the broad economic, political, environmental, social, and cultural context shaping children's nutrition.

Over the last decade much attention has been given to identifying appropriate nutrition-specific interventions to address the immediate causes of undernutrition (#1 above), and a sub-set has been clearly identified as most effective. These are: periconceptual folic acid supplementation, maternal energy, protein, calcium and micronutrient supplementation, promotion of breastfeeding and appropriate complementary feeding of children, vitamin A and zinc supplementation for children, and management of acute malnutrition (Bhutta *et al*., 2013). Recently, efforts have been made to identify ways programs with links to nutrition, such as those in agriculture, safety nets, early child development and schooling, can be made more nutrition sensitive and thereby more directly address some underlying causes of child undernutrition (#2 above) (Ruel, Alderman, & The Maternal & Child Nutrition Study Group, 2013).

With respect to the basic causes of child undernutrition, the emphasis has been on building an enabling environment for undernutrition reduction through rigorous impact evaluations of nutrition programs, advocacy strategies, investment in building capacity, domestic resource mobilization, and politics and governance (*Lancet*, 2013, Framework for Action). Regarding the latter, there is a growing focus on understanding how factors such as political commitment, leadership, and accountability can create a more supportive environment for child nutrition (Gillespie *et al*., 2013; Haddad, 2012; Mejia Acosta & Haddad, 2014; Te Lintelo, Haddad, Leavy, & Lakshman, 2014). Beyond factors with a nutrition focus, the evidence on the key importance of income growth continues to accumulate (Headey, 2012; Ruel *et al*., 2013).

In this paper we aim to contribute to the growing evidence base needed for prioritizing action to inform the post-2015 nutrition and wider development agendas by focusing in on the roles of the underlying and basic determinants of child undernutrition. Interventions directed at these determinants are not necessarily nutrition-specific, nutrition-sensitive, nor nutrition-focused. Yet they may nevertheless be powerful drivers of undernutrition reductions because they address its root causes.

We investigate the following six questions. First, which underlying and basic determinants have been important in driving down prevalences of child stunting over the last 40 years and what are their relative strengths of impact? Second, are there any regional differences in these drivers? Third, has there been a structural shift in the importance of different determinants pre and post 2000, the year marking the beginning of the MDG era? Fourth, what are the priority determinants to tackle undernutrition in the post-MDG era in South Asia and Sub-Saharan Africa? Fifth, stunting has replaced underweight as the preferred measure of child undernutrition for setting and monitoring international goals (UNICEF, 2013).[1] How does this shift affect identification of our priorities for the future? Finally, how important is attention to governance for future declines in stunting?

To answer the questions we conduct a cross-country econometric analysis using data from 116 developing countries collected over 1970–2012. The conceptual framework we use, rooted in the UNICEF (1990) model, together with data availabilities lead us to investigate the roles of the following food-care-health determinants: the quantities of food available at a national level and the diversity of that food; women's education and the degree of gender equality; and access to safe water and sanitation. At a more fundamental level of causality we investigate the influence of national income and the quality of governance in countries through various pathways.

In our analysis we pay close attention to ensuring that a causal relationship, if it exists, is identified and consistently estimating the magnitude of effect of determinants. To do so our choice of explanatory variables is based on a strong conceptual understanding of the determinants of child undernutrition, we utilize panel data techniques to reduce bias due to omitted variables, we explicitly test for the presence of endogeneity for all determinants considered, and we assess the performance of all instruments employed to do so.

The paper is a follow up to Smith and Haddad (2000), which used underweight prevalences (the MDG-1 child undernutrition indicator), and data from 63 countries collected over 1970–95. In addition to benefitting from a longer time series and a much larger set of countries, this paper improves on our original work in several ways.

First, it uses the now-recognized preferred measure of undernutrition, stunting, as the outcome of interest. Second, reflecting increased understanding of the importance of dietary quality to children's nutritional status (Arimond & Ruel, 2004), in investigating the role of food, it expands beyond national food availabilities to include a proxy measure of the quality of that food supply: the percent of available food that comes from non-staples. Further, to address health environment quality, it now includes access to sanitation, for which an historical data set has become available, rather than

only access to safe water. This inclusion is particularly timely given the new interest in sanitation coverage and quality (Chambers and von Medeazza, 2013; Spears, 2013).

Third, at the level of the basic determinants, our original paper looked at income and democracy.[2] But democracy is only one of many dimensions of governance. Since the publication of Smith and Haddad (2000), governance more broadly has risen up the health (Farag *et al*., 2013; Halleröd, Rothstein, Daoud, & Nandy, 2013) and nutrition agendas (Gillespie *et al*., 2013; Haddad, 2012; Mejia Acosta & Fanzo, 2012; Nishida, 2009; Pelletier *et al*., 2012). Data availabilities now allow us to explore a variety of dimensions of governance beyond democracy, dimensions that we hypothesize to be important for understanding the rate and pattern of undernutrition reduction. This is the first cross-country panel study to examine the relationship between stunting and governance within a rigorous econometric framework.

Fourth and finally, we move the field forward by looking at both long-run impacts (using a country-fixed effects approach) and short-run impacts (using first-differences), both of which are important for informing current policy choices.

The next section lays out our conceptual framework. In Sections 3 and 4, we discuss the data and measures employed and our empirical strategy in detail. The results are presented in Sections 5 and 6. In Section 7 we describe policy priorities for accelerating reductions in undernutrition in the coming decades with a special emphasis on South Asia and Sub-Saharan Africa. Additionally, we conduct an analysis of the differences in our main results when underweight is used as the measure of undernutrition rather than stunting. Section 8 summarizes our findings and provides concluding comments.

2. THE DETERMINANTS OF CHILD UNDERNUTRITION: CONCEPTUAL FRAMEWORK

Figure 1 presents our conceptual framework, which is founded on the original UNICEF framework for the "Causes of child malnutrition and death" (UNICEF, 1990) and is reflected in the *Lancet* 2013 Framework for Action (Black *et al*., 2013). The framework lays out the hierarchical relationship between the immediate, underlying, and basic determinants of child nutritional status.

The *immediate determinants*, which manifest themselves at the level of the individual child, are dietary intake (energy, protein, fat, and micronutrients) and health status. These factors themselves are interdependent. A child with inadequate dietary intake is more susceptible to disease; disease in turn depresses appetite, inhibits the absorption of nutrients in food, and competes for a child's energy.

The *underlying determinants*, which impact child nutritional status through the immediate determinants, manifest themselves at the household level. The first, household food security, is assured access to enough food of adequate quality for living an active healthy life. The second is the quality of caring practices for children and women. Examples of caring practices for children are child feeding, health-seeking behaviors, and cognitive stimulation. The most obvious aspect of care for women that affects children's nutritional wellbeing is care and support during pregnancy and lactation. Women are typically the main caretakers of children after birth, and in order to provide quality care they need continued adequate food consumption and health care, rest, and measures to protect their mental health, such as protection from abuse. The third underlying determinant, health environment and services, conditions children's exposure to pathogens and the use of preventative and curative health care. Elements of a health environment include access to safe water, to sanitary facilities for disposing of human waste, to health services, and to shelter.

Finally, the *basic determinants*, which in turn impact nutritional status through the underlying determinants, manifest themselves at broader geographical levels, such as national, regional, or global. They form the economic, political, environmental, social and cultural context in which children's nutritional status is determined. A key basic determinant, income, can influence undernutrition through two main routes. First, higher income is strongly correlated with poverty reduction (Ruel *et al*., 2013) and so is an indicator of increased household ability to pay for nutrition inputs such as food, water, sanitation, and medical care. Second, higher national income, when brought about through a pro-poor pattern of growth, is associated with greater provision of public services such as health services, social protection, and education (OECD, 2006).

A second key basic determinant concerns whether a country's government is responsive to its people's needs and responsible in its efforts to meet them. Governance has been defined as "the traditions and institutions by which authority in a country is exercised. This includes the process by which governments are selected, monitored and replaced; the capacity of the government to effectively formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions among them" (World Bank, 2013c). For our purposes, at its core, governance is about whether the relationship between the state, citizens, and intermediate institutions promotes or impedes development generally, and children's nutrition status more specifically.

Governance has many definitions. The data set we utilize (see Section 3(b) below) is organized around five dimensions:

- Bureaucratic effectiveness;
- Law and order;
- Political stability;
- Restraint of corruption; and
- Democratic accountability.

How might these five dimensions be relevant to facilitate or impede efforts to accelerate reductions in child undernutrition?[3]

Bureaucratic effectiveness concerns the quality of public services and the civil service, including policy formulation and implementation, and regulation of the private sector. It is important for effectively providing public services and programs that support children's nutrition status such as safe water, sanitation, education, and public food safety net programs (Lipsky, 2010). Effective functioning of countries' bureaucracies is particularly important to child undernutrition because addressing it requires a multisectoral effort and vertical integration of different levels of government. It thus puts strong demands on public agencies (Levinson, Pinstrup-Andersen, Pelletier, & Alderman, 1995). It also requires strong accountability within government bureaucracies because multisectorality can fragment leadership, capacity, and resource flows. Similarly, a strong regulatory environment is necessary as the private sector produces a number of products that if marketed irresponsibly can harm the nutrient consumption of children under 2 years of age—effective regulation and enforcement of that regulation is vital for the nutrition status of the most vulnerable (Moodie *et al*., 2013).

A strong system of *law and order* is founded on a solid and impartial legal system in conjunction with popular observance

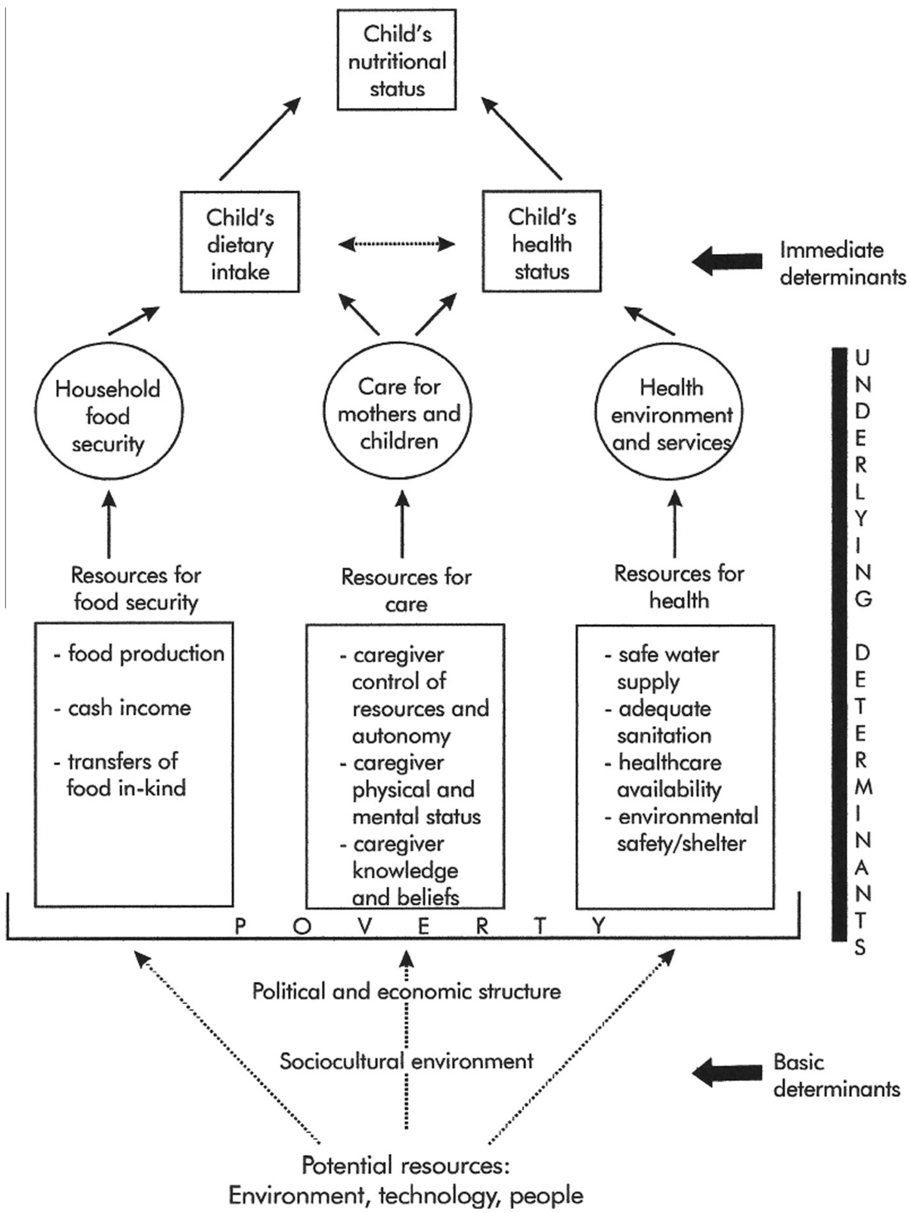

Figure 1. *Conceptual framework guiding empirical analysis. Sources: Adapted from UNICEF (1990, 1998), Engle, Menon, and Haddad (1999).*

of the law. *Political stability* rests on a government's ability to carry out its declared programs when in office and to gain office and stay in office through constitutional and non-violent means. Both are essential for providing reliable public services, creating an environment conducive to the economic stability of households, and the functioning of markets for essential nutrition inputs such as food. Much like natural disasters, violence due to conflict is estimated to have large and permanent effects on nutrition status (Rico, Fenn, Abramsky, & Watts, 2011). Both law and order and political stability allow governments to fulfill their role of protecting citizens from such violence.

Restraint of corruption, that is, restraint of the exercise of public power for private gain, is important as many nutrition interventions involve the transfer of valuable commodities, such as food and drugs, at subsidized rates, which creates multiple opportunities for leakage (Gelb & Decker, 2012).

Finally, *democratic accountability*, including respecting and protecting the rights and civil liberties of all citizens, represents how responsive a government is to its people. The irreversibility of early childhood undernutrition means that public responsiveness in supporting families to meet the needs of young children is vital. Democratic accountability and its herald, transparency, are particularly important for nutrition as most forms of undernutrition are invisible, both because the clinical signs are not obvious unless at their most extreme and because of infrequent collection of nutrition data. Hence public awareness of the magnitude and consequences of the problem is low, and voice is essential to stimulate timely action. In addition, nutrition resource flows, being fragmented across multiple authorities, are also notoriously nontransparent, undermining accountability mechanisms (Action Against Hunger, 2012).

3. DATA AND MEASURES

Our analysis of the underlying determinants of child undernutrition is based on data for 116 out of a total of 132 developing countries over the 42-year period during 1970–2012.[4]

The availability of high-quality, nationally representative undernutrition data is the limiting factor for inclusion of countries. With the dramatic increase in the availability of national data on child undernutrition over the last two decades, we are able to include a full 88% of developing countries, representing 96% of the developing-world population (see Appendix Table 9). Five of the developing regions are represented by near or over 90% of their countries: South Asia, Sub-Saharan Africa, East Asia and the Pacific, Middle East and North Africa, and Latin America and the Caribbean. The only region with low coverage (only 61% of countries) is developing Europe and Central Asia. The coverage for the basic-determinants analysis is lower than that for the underlying-determinants due to the shorter time coverage of the governance indicators employed (see Table 9).

(a) *Child undernutrition*

Among the three commonly employed measures of child undernutrition—stunting, underweight, and wasting—the dependent variable chosen for this analysis is stunting. Stunting is a result of inadequate growth of the fetus and child and results in a failure to achieve expected height compared to a healthy, well-nourished child of the same age. It is a cumulative indicator of growth failure and a marker of chronic insufficient protein and energy intake, frequent infection, sustained inappropriate feeding practices, and impaired brain development (Black *et al*., 2013; UNICEF, 2013).

Our rationale for employing stunting as an indicator of undernutrition is fourfold. First, as mentioned in the introduction, it has become the consensus measure among the international community to mark the damage that is done from the interaction of poor diet and repeated infections (Black *et al*., 2013; UNICEF, 2013). Second, it is a measure of long-term, chronic undernutrition rather than undernutrition as a result of short-term fluctuations in dietary intake and/or health. It is thus particularly well suited to investigation of factors over the long historical period of interest. Third, stunting is more prevalent than either wasting (measuring acute undernutrition) or underweight (a composite measure of both chronic and acute undernutrition). Finally, in a world of rapidly rising overweight and obesity even in the poorest of countries, the chronic undernutrition signaled by stunting often persists even as the prevalence of underweight falls (de Onis *et al*., 2011). Given that underweight can misidentify cases of undernutrition, it also has the potential to misidentify its causes.

The measure of stunting employed is the percent of children under five years [5] whose height-for- age z-score is less than -2 standard deviations below the median of a global reference population of children who are well nourished and received key recommended caring practices. The current reference is the World Health Organization 2006 Child Growth Standards (de Onis, Garza, Victora, Bhan, & Norum, 2004). Most of the stunting data used in the econometric work, 89%, are from the World Health Organization's Global Database on Child Growth and Undernutrition (WHO, 2013a). Eight percent of the data points are either taken directly from Demographic and Health Survey (DHS) country reports or from UNICEF's Childinfo.org database. The remainder (3%) is from the World Development Indicators (World Bank, 2013b). [6] The mean prevalences of stunting for the underlying- and basic-determinants analyses, respectively, are 32.7% and 30.6%, ranging from 2 (Chile 2008) to 75 (Nepal 1975) (see Table 2).

In constructing our data set, data for each potential determinant of stunting were matched for each country by the year in which the stunting data are available. [7] Because we employ panel estimation techniques, we only include countries for which stunting data are available for at least two points in time. Nationally representative nutrition surveys have widely varying time intervals between surveys. We thus have an unbalanced panel, that is, the data are for different time periods within the 1970–2012 span for each country, and the number of data points differs by country as well. The total number of country-year observations for the underlying-determinants analysis is 534. For the basic-determinants analysis the number of observations is 383. For both, the average number of observations per country is 4.4 and ranges from 2 to 11.

Table 2. *Sample summary statistics*

Variable	Mean	Standard deviation	Minimum	Maximum	Number of observations
Underlying determinants					
Prevalence of stunting	32.7	14.6	2.0	75.0	534
Access to safe drinking water (%)	73.0	20.2	8.0	100.0	534
Access to improved sanitation (%)	52.0	29.0	1.0	100.0	534
Female secondary enrollment (%, gross)	48.2	28.5	0.0	119.4	534
Female-to-male life expectancy ratio	1.063	0.036	0.973	1.198	534
Per capita dietary energy supply	2,432	387	1,521	3,712	534
Dietary energy from non-staples (%)	40.2	11.9	14.9	65.8	534
Basic determinants					
Prevalence of stunting	30.6	14.3	2.0	68.3	383
Per capita GDP	3,935	3,348	262	15,699	383
Percent of population urban	46.5	20.4	9.3	92.5	383
Percent of population 0–14 years	37.8	7.4	16.9	50.0	383
Percent of population 15–64 years	57.7	5.7	47.4	73.5	383
Percent of population 65+	4.5	2.1	2.2	14.0	383
Governance indicators					
Governance index	0.512	0.122	0.11	0.80	380
Bureaucratic effectiveness	0.410	0.215	0.00	1.00	383
Law and order	0.467	0.204	0.09	1.00	383
Political stability	0.620	0.194	0.05	1.00	383
Restraint of corruption	0.489	0.188	0.00	1.00	383
Democratic accountability	0.570	0.223	0.00	1.00	380

(b) *Potential determinants of child undernutrition*

(i) *Underlying determinants*

In our treatment of the underlying determinants—household food security, maternal and child care practices, and health environment quality—rather than employing measures of the actual determinants themselves, we take a step back in the chain of causality and employ indicators of factors closely associated with the resources necessary for supporting them (see Figure 1). Our reasons for doing so are twofold. First, direct measurements are not widely available for all of the determinants. For example, while measures of the physiological aspects of caring practices, such as breastfeeding, immunizations, and prenatal care, are available at the national level, a direct measure of household food security is not.[8] Similarly, measures of the quality of health environments like the presence of pathogens in water are available for only small samples in small reference areas.

Secondly, there is ample evidence from the health, nutrition, and social science literatures on the importance of these proximal factors. Our goal here is to identify more distal, foundational factors that have contributed to reductions in child stunting. Note that some previous studies of the causes of child undernutrition have combined proximal and distal factors that determine them in a "quasi reduced-form" analysis (e.g., Headey, 2012). Since we are interested in accurately measuring the relative impacts of determinants on stunting over time, it is important that we identify the distinct causal impact of each and carefully group variables lying at the same level of causality.

For *household food security* we employ indicators of the amount of food available at the national level and, unlike Smith and Haddad (2000), the dietary diversity of the food supply, a very rough proxy for dietary quality.[9] National food availability is measured using countries' daily per-capita dietary energy supplies (denoted *des*), an indicator of the average amount of food available per person in a country. The diversity of the available food is measured as the percent of food energy derived from non-staple foods (e.g., vegetables, fruit, pulses and animal-derived foods) (*des_nstaples*). Energy-dense starchy staples, such as cereals, roots, and tubers, have only small amounts of bioavailable protein and micronutrients, leaving those consuming large amounts of them vulnerable to nutrient deficiencies (Arimond *et al*., 2010; Ruel, 2003). Both measures are derived from food balance sheets compiled by the United Nations Food and Agriculture Organization (FAO) based on country-level data on the production, trade, wastage, and uses of food commodities.[10] The data are from the FAOSTAT database (FAO, 2012).[11] Table 2 contains sample summary statistics.

For the *quality of care for mothers and children* we employ indicators of women's education and the degree of gender equality in countries. The focus on women is due to their key roles in giving birth to children, breastfeeding them, and as daily caretakers. The educational attainment of women has a myriad of positive impacts on the quality of care they themselves receive during pregnancy and post-partum and on the quality of care for their children after they are born, ranging from duration of breastfeeding to health care seeking during illnesses (Ruel *et al*., 2013). The female gross secondary school enrollment ratio (denoted *femsed*) is used to measure women's education. This is chosen above primary school enrollment because it is more variable across countries (many developing countries are approaching 90% primary school enrollment rates for girls (United Nations, 2013)) and because it may well be more important via its direct and indirect effects such as delaying the age of first pregnancy (Viner *et al*., 2012). The education data are from the World Development Indicators (World Bank, 2013b).[12]

The degree of gender equality and the related concept of women's empowerment are now widely recognized as important determinants of child undernutrition through their impact on such factors as women's control of their time and household income and on their mental health, confidence, and self esteem (Bhagowalia, Menon, Quisumbing, & Soundararajan, 2012; Smith, Ramakrishnan, Ndiaye, Haddad, & Martorell, 2003). To measure the degree of gender equality, we use a marker of the health status and survival of females relative to males: the ratio of female life expectancy at birth to male life expectancy at birth (denoted *lfexprat*). The data are from the World Development Indicators (World Bank, 2013b). A long life is universally valued, not only for its own sake, but also because it is necessary for carrying out a number of accomplishments (or "capabilities") that are positively valued by society (Sen, 1998). Writes Sen (1998): Comparisons of the mortality and, conversely, life expectancy of women and men can be used to "throw light on some of the coarsest aspects of gender-related inequality." (p. 10). Socially induced inequalities in life expectancy favoring males reflect discrimination against females as infants, children, and adults, and are a rough proxy indicator of the cumulative investments in women relative to men throughout the human life cycle (Smith & Haddad, 2000).[13]

While gender equality and women's empowerment are distinct concepts (Malhotra, 2012), gender equity in health status is thought to be a precursor, or enabling condition for women's empowerment (Grown, 2008, chap. 3), defined as women's "ability and freedom to make strategic life choices where this option was previously denied them" (Malhotra, 2012, p. 27). At a country level, women's empowerment itself can be measured using such indicators as women's educational attainment relative to men's, women's participation in the labor markets, and women's political participation. We find that the gender life expectancy ratio is positively correlated with several such direct empowerment indicators, confirming its precursor role in women's empowerment. Subsets of our data set for which data on indicators are available give the following correlations:

- Ratio of female-to-male adult literacy rates, 0.472 ($p = 0.000$, $N = 325$);
- Ratio of female-to-male gross primary enrollment rates, 0.321 ($p = 0.000$, $N = 504$);
- Ratio of female-to-male gross secondary enrollment rates, 0.404 ($p = 0.000$, $N = 455$);
- Proportion of seats held by women in parliament 0.103 ($p = 0.028$, $N = 465$).

The gender life expectancy ratio is not correlated with indicators of women's labor market participation.[14]

Finally, for *health environment quality* we employ measures of countries' populations with access to safe water (denoted *safew*) and to sanitation (denoted *sanit*), both of which are important for maintaining a sanitary environment and preventing the spread of illness to and among young children (UNICEF, 2013). We are not able to include a third dimension, access to good quality health services, because of a lack of data.[15] While country definitions deviate, the World Health Organization considers safe drinking water to be treated surface water or untreated water from protected springs, boreholes, and wells. In general, countries define sanitary facilities to be those that break the fecal-oral transmission route (Gleick

et al., 2012). The large majority (90%) of the safe water and sanitation data are from the WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation (WHO/UNICEF, 2013).[16] The remaining data points are reported by the Pacific Institute, being originally from the United Nations Environment Program (UNEP) and the World Resources Institute (WRI) (Pacific Institute, 2013). A limitation of all the health environment quality data is that definitions can vary from country to country and from year to year within the same country. For this reason the safe water and sanitation data were examined closely for unreasonable breaks in trends within countries.

(ii) *Basic determinants*

The measure of national income we employ is real per-capita Gross Domestic Product (GDP) expressed in constant purchasing power parity (PPP) -comparable 2005 U.S. dollars (denoted *gdp*). GDP in local currencies is converted to international dollars using PPP exchange rates so that the final numbers take into account the local prices of goods and services that are not traded internationally. The large majority of the data points (91%) are from the WDI, which reports for 1980-onward. The remaining are conversions from GDP in local currencies to PPP GDPs provided by the Institute for Health Metrics and Evaluation (James, Gubbins, Murray, & Gakidou, 2012). The mean per-capita GDP for the sample is $3,533, ranging widely from 262 (Democratic Republic of the Congo in 2001) to 15,600 (Libya in 2007) (see Table 2).

To measure the quality of governance in countries we employ International Country Risk Guide (ICRG) indicators published by the Political Risk Services Group (PRS, 2013). The indicators are indexes corresponding to the five dimensions of governance laid out in Section 2: (1) bureaucratic effectiveness; (2) law and order; (3) political stability; (4) restraint of corruption; and (5) democratic accountability.[17] The data are available from 1982-onward and, to render them comparable across countries and over time, are compiled based on PRS experts' subjective analyses of political information organized on the basis of pre-specified "risk components". We construct an overall measure of the quality of governance (denoted *gov*) as the simple mean of the five indicators for each country-year data point after placing each on a 0–1 scale so that they have equivalent ranges. This index ranges from 0.11 to 0.80.

Starting with Knack and Keefer (1995), the ICRG governance indicators have been used extensively to analyze the impact of governance on economic growth and the impact of foreign aid on governance quality (e.g., Rajan & Subramanian, 2007). They have also been employed in studies of the relationship between governance, public spending, and child health outcomes (Hu & Mendoza, 2013; Rajkumar & Swaroop, 2008). Comparisons of the quality of the ICRG indicators with other indicators of governance can be found in Arndt and Oman (2006) and World Bank (2013d).

For the basic determinants analysis we account for the major demographic changes that have taken place over the last 40 years by including controls for degree of urbanization and the age structure of populations. Urbanization is measured as the percent of countries' populations living in urban areas (denoted *urban*) as defined by national statistical offices. To measure age structure, a three-stage variable is used consisting of the percent of countries populations that are 0–14 years old, the percent that are 15–64 years old, and the percent that are 65 or older (*perc0_14*, *perc15_64*, *perc65p*). The data are from the World Development Indicators (World Bank, 2013d).

4. STRATEGY FOR EMPIRICAL ANALYSIS

Our goal is to identify key determinants of child stunting in developing countries, measure their relative strength of impact and, eventually, estimate their contributions to the reductions in stunting that have taken place since the 1970s. In doing so we take a number of steps to ensure that a causal, rather than simply associative, relationship is identified and that the empirical results are as reliable and precise as possible.

The first step is to base our choice of potential determinants on the theory implied by the conceptual framework of the last section. As mentioned above, there is a hierarchical relationship between the determinants, with basic determinants influencing undernutrition through the underlying determinants, and the underlying determinants in turn influencing undernutrition through the immediate determinants. This relationship guides us to conduct separate analyses for variables that lie at different levels of causality. To do so, we undertake estimation for the underlying and basic determinants in turn, rather than combined. Doing so avoids "quasi-reduced form" estimation (Behrman & Deolalikar, 1988) whereby variables that structurally determine one another are included in the same estimating equation, thus crowding out more proximate determinants and biasing coefficient estimates. Providing separate estimating equations for the underlying and basic determinants also allows us to estimate the relationship *between* the underlying and basic determinants, answering the important question: Which underlying determinants do the basic determinants work through?

Mathematically, the approach is as follows. We first regress all of the indicators of the underlying determinants introduced in the last section on stunting (ST):

$$\mathrm{ST}_{it} = f(safew_{it}, sanit_{it}, femsed_{it}, lfexprat_{it}, des_{it}, des\_nstaples_{it}), \quad (1)$$

where i denotes countries and t denotes time. We then regress the indicators of the basic determinants on stunting:

$$\mathrm{ST}_{it} = f(gdp_{it}, gov_{it}, urban_{it}, perc0\_14_{it}, perc15\_64_{it}, perc65p_{it}). \quad (2)$$

Finally, each underlying-determinant indicator is regressed on the basic-determinant indicators:

$$safew_{it} = f(gdp_{it}, gov_{it}, urban_{it}, perc0\_14_{it}, perc15\_64_{it}, perc65p_{it})$$
$$\vdots$$
$$des\_nstaples_{it} = f(gdp_{it}, gov_{it}, urban_{it}, perc0_{14it}, perc15_{64it}, perc65p_{it}). \quad (3)$$

The second step we take to ensure that a causal relationship is identified and that the empirical results are as reliable as possible is to exploit the panel nature of the data to control for any unobserved heterogeneity across countries in the form of time-invariant country characteristics that affect either child stunting, its measured determinants, or both. Examples of these factors are deeply engrained dietary patterns and cultural norms related to child care, climate, geography, and the presence of continuous government nutrition programs. To do so we first estimate a country fixed-effects (FE) model, which relies on the "within" variation (changes over time for each country) as follows:

$$Y_{it} = \alpha + \sum_{k=1}^{K} \beta_k X_{k,it} + \mu_i + v_{it}, v_{it} \sim N(0, \sigma^2). \quad (4)$$

In Eqn. (4) α is a scalar, the βs are regression coefficients, one for each independent variable X_k, and the μ_i are the unobservable country-specific, time-invariant effects. The v_i is a stochastic error term. The actual estimating equation is obtained by transforming the observations on each variable into deviations from country-specific averages:

$$Y_{it} - \overline{Y_i} = \sum_{k=1}^{K} \beta_k (X_{k,it} - \overline{X_{k,i}}) + (\mu_i - \overline{\mu_i}) + (v_i - \overline{v_i}). \quad (5)$$

Since the μ_i are time invariant, $(\mu_i - \overline{\mu_i}) = 0$, and the terms drop out of the model. Unbiased and consistent estimates of the β_k can be obtained using Ordinary Least Squares (OLS) estimation if the error term does not contain components that are correlated with an independent variable. [18]

We can control for unobserved heterogeneity across countries in an alternative manner to fixed-effects estimation, and in the process gain insight into the timing dimension of the determinants of child stunting, by taking a first-difference approach. Here the dependent variable is the *change* in stunting and the independent variables the *change* in each determinant between consecutive within-country observations, modeled as follows:

$$Y_{it} - Y_{i,t-1} = \sum_{k=1}^{K} \beta_k (X_{k,it} - X_{k,i,t-1}) + \gamma Y_{i,t-1} + (v_{it} - v_{i,t-1}), (v_{it} - v_{i,t-1}) \sim N(0, \sigma^2). \quad (6)$$

In Eqn. (6) we include the term $Y_{i,t-1}$ to take into account the stunting prevalence at the beginning of the period. Following Headey (2012), we test for and report a "trends fixed-effects" model to account for the possibility of further omitted country-specific factors that influence changes in stunting.

It is important to note that, being reliant on the within-country variation in the dependent and independent variables, the FE estimates will refer to a longer time period than the first-difference estimates. The average total length of time between the first and last observations for a country is 15 years (in the case of the underlying determinants) or 20 years (basic determinants). By contrast, the average spell length based on consecutive within-country observations is 5 years. Thus the fixed-effects analysis can be interpreted as examining the long-run impact of the independent variables and the first-differences approach the short run impact (over roughly five years).

The third step taken to ensure accuracy of the estimated coefficients is to perform statistical tests of omitted variable bias and functional form. These are the Ramsey RESET test and the Linktest provided by STATA. If omitted variable bias is a problem then we cannot be confident that we are estimating the magnitude of impact of the various determinants of stunting with accuracy.

Fourth, to more directly ensure that a causal effect is being identified, and that only the causal portion of the observed relationship is represented by the regression coefficient estimates, we conduct endogeneity tests for all determinants. [19] If found, we take this endogeneity into account by estimating the above equations using instrumental variables (IV). Doing so is important for detecting and correcting for reverse causality (in which stunting itself affects an independent variable), incidental association (in which a third, omitted variable is correlated with both stunting and an independent variable), and attenuation bias due to measurement error.

To test for endogeneity, we use current techniques to ensure that the instruments used for testing are relevant or "strong" (correlate sufficiently with the variable of interest) and valid (do not affect stunting through channels other than the variable of interest) (Baum, Schaffer, & Stillman, 2007; Bazzi & Clemens, 2013). With regard to instrument relevance, we test whether the instruments are strong enough to remove a substantial portion of the OLS bias if it exists. To do so we report the Kleibergen-Paap rk Wald first-stage F statistic and compare it to critical values developed by Stock and Yogo (2005) for weak-instruments hypothesis tests. We test the null hypothesis that the maximum bias in the coefficient estimate for each potentially endogenous variable is greater than 5%, 10%, or 20% of the OLS bias. This test identifies cases of weak instruments, which can arise even when the correlations between the endogenous regressors and instruments are significant at conventional levels (5% and 1%). [20] To test for instrument validity we employ Hansen's J test for overidentification of all instruments, which is robust to heteroskedasticity and within-group correlation. If the J-statistic p-value is <0.1, the instruments are considered to not be valid. Given relevant and valid instruments, the test for endogeneity we employ is implemented using the STATA command xtivreg2 developed by Schaffer (2010). [21]

Lastly, before finalization of the data sets, tests for observations having undue influence on the magnitude of regression coefficients, whether due to erroneous values of one of the variables or otherwise, were conducted. To detect general outliers, leverage-*versus*-squared residual plots were used. To detect variable-specific outliers, added variable plots, in which the values of each independent variable adjusted for the others following fixed-effects regression are plotted against stunting, were used. Subsequently, several observations were discarded. [22]

5. IMPACTS OF THE UNDERLYING DETERMINANTS OF CHILD STUNTING

The estimation results for the underlying-determinants are presented in Table 3. The endogeneity tests reveal that the coefficient estimates likely do not suffer from the effects of reverse causality, spurious correlation, or measurement error. For each determinant it was possible to identify three to four appropriate instruments for conducting the tests (see Table 10). In the case of only one, the female-to-male life expectancy ratio, the estimated maximal relative bias of the instrumental variables (IV) estimates exceeds 10%, indicating weak instruments. The bias is still not excessive, at less than 20%. All instrument sets pass the overidentification and Durbin–Wu–Hausman tests. [23] Given that none of the hypothesized determinants was found likely to be endogenous, we consider OLS estimates to be preferred. [24]

The OLS-Fixed-effects results for the long-term impacts of the underlying determinants on child stunting are presented in Table 3, column (1). The coefficients of all six hypothesized determinants are negative and statistically significant, signifying that they have all served to reduce child undernutrition over the last 40 years. Consistent with household-level analyses of gender equality/women's empowerment and child nutrition, the female-to-male life expectancy ratio has a non-linear relationship with stunting. It has a stronger (negative) impact at lower levels than high, probably due to reduced breastfeeding levels among women with greater decision making power (Smith *et al.*, 2003). The natural log form of this variable is thus used in the regressions. The Ramsey RESET and Link-tests indicate that an appropriate functional form has been used and omitted variable bias is not likely a problem. A correlation between the fixed effects terms and the fitted values of

Table 3. *Estimation results—relationship between stunting and the underlying determinants in the long and short term*

	OLS-fixed effects (Mean time span: 15 years)		First differences (Mean spell length: 5 years)	
		With regional differences		With trend fixed effects
	(1)	(2)	(3)	(4)
Access to safe water	−0.112	−0.112	−0.055	0.015
	(−3.82)***	(−3.39)***	(−1.96)*	(−0.51)
Access to sanitation	−0.127	−0.108	−0.014	0.038
	(−3.34)***	(−2.89)***	(−0.37)	(−0.88)
Female secondary school enrollment	−0.113	−0.101	−0.076	−0.071
	(−3.84)***	(−3.41)***	(−2.54)**	(−2.35)**
Ln(female-to-male life expectancy ratio)	−73.1	−61.5	−74.2	−48.7
	(−4.05)***	(−3.11)***	(−3.43)***	(−2.01)**
Per capita dietary energy supply	−0.0074	−0.0057	−0.0077	−0.0053
	(−3.35)***	(−2.48)**	(−3.60)***	(−2.40)**
Percent of dietary energy from non-staples	−0.282	−0.442	−0.041	−0.008
	(−2.55)***	(−3.41)***	(−0.46)	(−0.08)
Initial stunting prevalence			−0.085	−0.526
			(−5.32)***	(−5.73)***
ln(life expectancy ratio)*South Asia		−91.4		
		(−1.76)*		
Dietary energy supply*LAC		−0.0089		
		(−2.66)***		
Energy from non-staples*SSA		0.489		
		(−2.16)**		
Number of observations	534	534	418	404
Number of countries	116	116	116	102
R-squared	0.628	0.463	0.155	0.078
Corr(X_β, μ_i)	−0.304	−0.849	–	−0.856
Ramsey RESET test (*p*-values)	0.307	0.078*	0.746	0.061*
Linktest (*p*-values)	0.516	0.463	0.485	0.079*

Notes: t-Statistics (in parentheses) are robust to heteroskedasticity and clustering by country.
Stars represent statistical significance at the 10% (*), 5% (**) and 1% (***) levels.

stunting of −0.3 suggests that the FE model is preferable to a Random Effects model (Clark & Linzer, 2013), and that the accuracy of the estimates is improved by controlling for time-invariant country fixed effects.[25]

We can affirm that it is not only gender inequality in general, but women's empowerment as well, that reduces child stunting. When we replace the gender life expectancy ratio with a more direct indicator of women's empowerment, the ratio of female-to-male gross secondary enrollments (RSE), we also find a negative impact on stunting. The coefficient on the ratio is −0.071 ($p = 0.053$, $N = 447$). An index combining various indicators, including the RSE, the percent of the labor force that is female, and the percent of parliamentarians who are female, yields a similarly negative regression coefficient (−1.7, $p = 0.032$, $N = 386$).[26]

We next tested for and found some regional differences in the coefficient estimates (Table 3, column 2).[27] First, the female-to-male life expectancy ratio has a far stronger impact in South Asia than the other regions. The coefficient of the log of the life expectancy ratio for South Asia ($-152.9 = -61.5 - 91.4$) is estimated to be nearly two times larger (in absolute value) than that of the developing countries as a whole (−73.1 [from column 1]).[28] Second, national food availability is found to have a stronger impact on stunting in LAC than the other regions, with the coefficient also being more than double that of the developing countries as a whole, possibly related to improved targeting of social programs involving food. The third difference is that the percent of dietary energy from non-staples appears to have near zero impact on child stunting in Sub-Saharan Africa when considering the entire 1970–2012 time span. There is some evidence from the data, however, that in more recent years the importance of dietary quality has increased, a finding that needs further investigation.[29] The regional differences for South Asia and Sub-Saharan Africa will be taken into account for the policy analysis of Section 7 below.

The first-difference results on the short-term impact of the underlying determinants yield a number of additional insights. Focusing on the preferred trend fixed-effects specification (Table 3, column 4),[30] first, they provide strong confirmation that women's education, the degree of gender equality, and the quantity of food available at a national level are indeed determinants of child stunting. Second, they indicate that these factors have an impact even in the short run. Women's education has just as strong an impact in the short as the long run, while the impact of gender equality and food availability is diminished in the short run. The other determinants—those representing health environment quality and the dietary quality of available food—can be expected to lead to reductions in national prevalences of stunting only over longer periods. A third insight is that the initial level of stunting, whose coefficient is strongly statistically significant, matters for future levels of stunting: controlling for changes in the underlying determinants considered here, the higher is the initial level of stunting, the greater is the decline in stunting over the ensuing years.

Recall that one of the goals of our analysis is to determine whether there has been any shift in the importance of different determinants pre and post 2000, the year marking the

beginning of the MDG era. Tests for structural differences in the coefficients of the underlying determinants before and after the year 2000 revealed none.

Returning to the fixed-effects results of column (1), we can now answer a primary question of this paper: How strong are the long-run impacts of each of the underlying determinants on child stunting? Table 4 reports elasticities derived from the regression coefficients along with related statistics for understanding the relative strengths of impact of the determinants.[31] While the elasticities give us some useful information, they are not all comparable because some variables (most notably the life expectancy ratio and dietary energy supply) have different units of measure with very different numerical ranges. Such measurement differences have a strong influence on the quantified relative strength of impact of the determinants and must be taken into account in making comparisons. The range of each variable is presented in column (2), with the minimums being set at the lowest found in the world since 1970 and the maximums set using normative standards of desirable target levels.[32]

Taking these ranges into account, the relative strengths of impact of the underlying determinants can be seen by examining how much of an increase in each over its range would be required to bring about the same change in the stunting prevalence. For example, how much would each have to be increased (holding the others constant), as a percent of its range, to reduce the undernutrition prevalence by one percentage point? These increases are given in Table 4, column (4).

From this standpoint, which ignores the relative cost of increasing each determinant, a rough ranking of the underlying determinants in terms of their potency in reducing child stunting is: percent of dietary energy from non-staples (greatest), followed by access to sanitation and women's education. Access to safe water, degree of gender equality as measured by the female-to-male life expectancy ratio, and per capita dietary energy supply have the lowest strength of impact, but do not fall far behind women's education. Figure 2 summarizes the underlying determinants' relative strengths of impact, showing the reduction in the prevalence of stunting in developing countries that can be expected from a ten percentage-point increase in each determinant over its range.

Tracing the historical record, we now answer a second key question of this paper: How much have the underlying determinants contributed to the reduction in stunting that has

Table 4. *Elasticities and related statistics for interpreting the strength of impact of the underlying determinants on child stunting*

Variable	Elasticity (at sample mean) (1)	Range a/ (2)	Increase needed to reduce stunting by one percentage point (3)	Number in (3) as a percent of range (4)
Access to safe water	−0.251	8–100	8.9	9.7
Access to sanitation	−0.201	1–100	7.9	8.0
Female secondary school enrollment	−0.166	0–102	8.9	8.7
Female-to-male life expectancy ratio	−2.237	0.965–1.105	0.0145	10.4
Per capita dietary energy supply	−0.550	1,520–2,940	135	9.5
Percent of dietary energy from non-staples	−0.347	14.9–68.0	3.5	6.7

a/ For each variable, the range varies from the lowest value among developing countries since 1970 to the desirable target level. The target levels for access to safe water and sanitation are set at a straightforward 100%. That for female second school enrollment is the 2010 mean among OECD countries. That for the life expectancy ratio is the 2010 value for Argentina, which has the maximum ratio among the top-five-ranked countries on the 2010 Women Disadvantage Index (Permanyer, 2013). This index was chosen over the UNDP's Global Inequality Index to identify a reference country because of its greater cross-country comparability. The target level for dietary energy supply (DES) is set at the median value between the current energy supply (3,370) and energy requirement (2,510) of the developed countries. The current DES of these countries was not employed because of the excess consumption, and the high obesity and chronic disease prevalences, associated with it. The target level for the percent of calories from non-staples is set at the current developed-country mean.

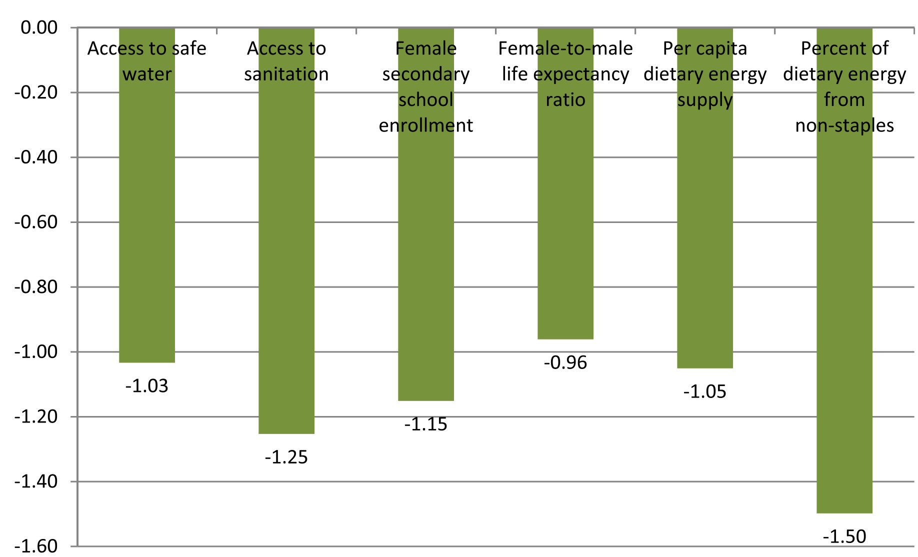

Figure 2. *Estimated reduction in prevalence of stunting due to a 10 percentage-point increase in determinant over its range.*

taken place over the forty-year period during 1970–2010? These contributions are based on two factors: (1) the strength of impact of each determinant on child stunting (as represented by the regression coefficients in Table 3, column (1)); and (2) the amount by which each determinant has changed over the period (given in Table 5). Quantitatively, each determinant's absolute and percentage contribution is calculated as follows, using access to safe water (safew) as an example[33]:

$$-0.112 * \Delta safew \text{ and } \frac{-0.112 * \Delta safew * 100}{\Delta stunting}.$$

Table 5 shows trends in the underlying determinants over the 40-year period by decade. All have seen improvements. To understand how much each has changed in a relative sense it is useful to place them on an equivalent 0–100 point scale, as in Figure 3a. Access to safe water has increased the most over the period, followed by female secondary enrollments. Next are per-capita dietary energy supply and sanitation. The determinants that have increased the least are the percent of dietary energy from non-staples and the gender life expectancy ratio. Taking these changes into account, the last column in Table 5 reports the estimated contribution of each determinant. The total estimated contribution is a reduction of 24.5 percentage points. Of note is that this number is quite close to the estimated 25.1 percentage-point reduction that has actually taken place overall (Table 1).

Figure 3b summarizes the percent contribution of each underlying determinant considered here to the total estimated reduction in the prevalence of stunting. It is important to note that by excluding a key determinant of child nutritional status, access to health services, from this pie chart we do not intend to imply that it is not important. As noted above, it is excluded because of lack of data to measure it.[34]

Improvements in access to safe water and women's education have contributed the most to the estimated reduction, 25% and 22%, respectively, largely due to their ample increases over the period. The contribution of improvements in access to sanitation, national food availabilities, and the dietary quality of that food have also been substantial. For the developing countries as a whole the determinant that has contributed the least is gender equality, largely a reflection of the fact that the gender life expectancy ratio has increased very little over the

Table 5. *Trends in underlying determinants and estimated contributions to reduction in stunting, 1970–2010*

	1970	1980	1990	2000	2010	Total change 1970–2010	Estimated contribution to reduction in stunting (percentage points)
Access to safe water (%)	32.0	46.9	69.8	78.6	86.1	54.1	−6.1
Access to sanitation (%)	29.2	28.5	35.7	45.8	55.9	26.7	−3.4
Female secondary school enrollment (%)	18.4	30.8	34.7	51.9	66.8	48.4	−5.5
Female-to-male life expectancy ratio	1.033	1.049	1.050	1.051	1.053	0.020	−1.4
Per capita dietary energy supply (kcals)	2,085	2,228	2,401	2,563	2,686	601	−4.4
Percent of dietary energy from non-staples	29.6	31.9	35.0	39.4	42.8	13.2	−3.7
Total estimated contribution							−24.5

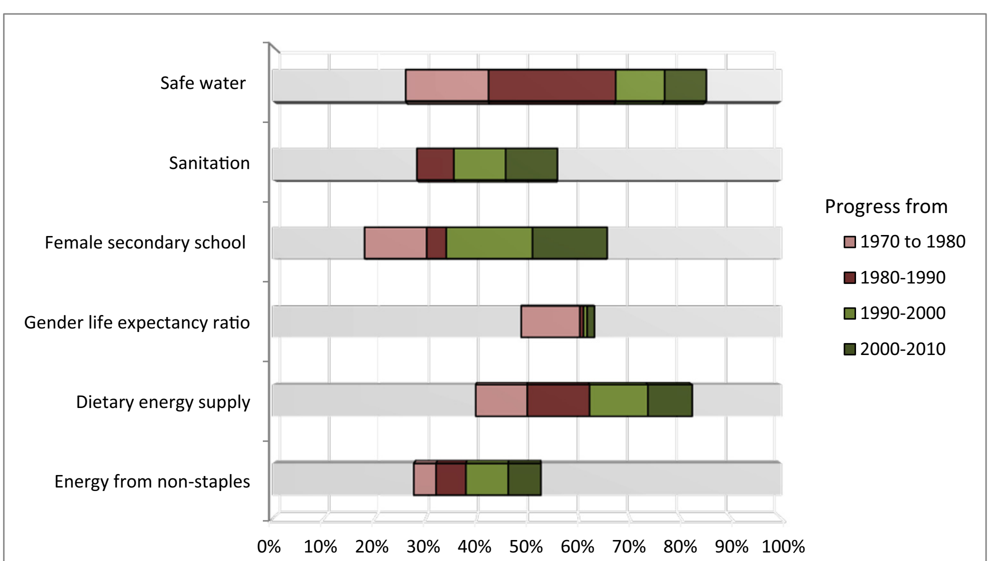

Figure 3a. *Increases in underlying determinants, 1970–2010 (On an equivalent scale of 0–100%). Note: The maximum values (100%) are set at desirable target levels (see notes to Table 4).*

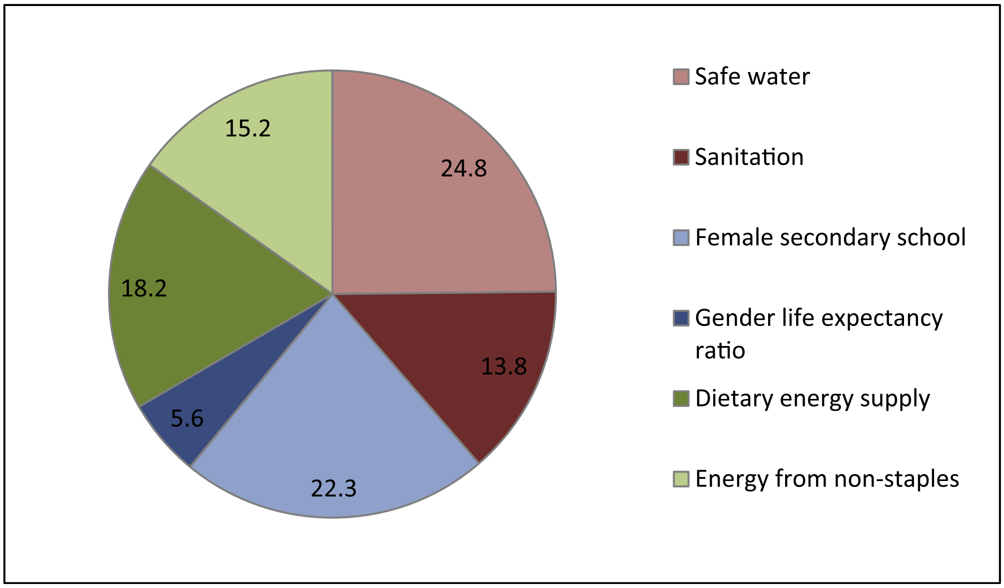

Figure 3b. *Contributions of underlying determinants to total estimated reductions in stunting, 1970–2010 (percent).*

study period (only 16% of its entire range). An overall observation is that each pair of determinants representing food security, the quality of caring practices, and health environment quality has made a solid contributed to the total estimated reduction.

6. IMPACTS OF THE BASIC DETERMINANTS OF CHILD STUNTING

The regression results for the impact of national income and the quality of governance on child stunting are given in Table 6. We present several models: OLS fixed-effects, six 2SLS fixed-effects models, the first including the overall governance index and the rest each indicator of its five dimensions in turn, and finally a first-difference model examining impacts in the short run. GDP per capita is entered into the regression equations in natural logs due to its strong non-linear relationship with stunting: its impact is strong at low levels of GDP, gradually weakening as GDP increases. Unlike the underlying-determinants analysis, here the Ramsey RESET test indicates the possibility of mis-specification issues for all models presented due to functional form mis-specification or omitted variables.[35] Thus we do not test for regional differences nor conduct extensive policy analysis based on the magnitudes of the coefficient estimates.

(a) *National income*

Starting with income, endogeneity testing strongly points to IV/2SLS estimates as preferred over OLS due to the endogeneity of per-capita GDP. The set of instruments used for testing are drawn from the numerous studies of the determinants and effects of economic growth (e.g., Brückner & Lederman, 2012; Dell, Jones, & Olken, 2012; Rajan & Subramanian, 2007). Those that are valid in this context include the real investment share of GDP, M2 (money and quasi money) as a percent of GDP, and cereal yields (see Appendix Table 10). Of concern is the possibility of reverse causality given the known deleterious long-run effects of childhood stunting on people's productivity and on countries' overall development. In the presence of such reverse causality, OLS estimates will be biased downward as they include the negative feedback effect of stunting on income. On the contrary we find that OLS estimates are biased upward, that is they imply that income has less impact on stunting than it truly has. As can be seen in Table 6, FE-2SLS coefficient estimates (columns 2–7) are more than double that of the OLS estimate (column 1). This finding suggests the possibility that OLS estimates are subject to attenuation bias due to measurement error in the income data, discussed by Miguel, Satyanath, and Sergenti (2004) or, despite the use of country fixed-effects to control for time-invariant factors, bias due to omission of important factors. Whatever its source, the bias is larger in magnitude than any due to reverse causality.[36]

Turning to the first-differences results (column 8), we find that for *changes* in income over short periods there is no evidence of attenuation bias or bias due to reverse causality. Endogeneity testing points to OLS estimates as preferred. The results indicate that income continues to have an impact in the short run although, as would be expected, it is weaker than in the long run.

Overall, the fixed-effects and first-difference results point to a strong and statistically significant negative causal effect of national income on child stunting. For the countries as a whole, a 10% increase in per-capita GDP leads to a 6.3% long-run decrease in the stunting prevalence.[37] This is on par with that derived from estimates recently reported by Ruel *et al.* (2013) of 5.9% and considerably higher than those reported in World Bank (2013a) of 4.5%, both of which used a country fixed-effects approach but did not correct for endogeneity. Over the short term, roughly five years, we find that a 10% increase in GDP leads to a 1.7% decrease in stunting prevalence.[38] This estimate is in line with first-difference estimates reported by Headey (2012) of 1.8 and Heltberg (2009) of 2.0. Testing for structural differences in the relationship between stunting and income before and after 2000 indicate no notable difference.

Table 7 documents the causal pathways of income, summarizing whether it has an impact and, if so, the direction of its impact on each of the underlying determinants of child stunting (see Eqn. (3) in Section 4 for the model underlying these results). National income has a broad reach. We find that it reduces child stunting by facilitating access to sanitation, increasing the percent of women who have a formal education, and increasing both the quantity and quality of food available

Table 6. *Estimation results—relationship between stunting and the basic determinants in the long and short term*

	Country fixed effects (Mean time span: 20 years)							First differences-country fixed effects (Mean spell length: 5 years)
	OLS	2SLS						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Per capita GDP)	−8.2	−19.4	−19.4	−21.0	−19.9	−20.1	−20.9	−5.3
	(−3.29)***	(−5.34)***	(−5.25)***	(−5.64)***	(5.25)***	(−6.20)***	(−5.86)***	(−1.82)*
Governance								
Overall index (combining all five dimensions)	−9.7	−8.3						3.6
	(−3.40)***	(−2.56)**						(1.17)
Bureaucratic effectiveness			−3.9					
			(−2.10)**					
Law and order				−4.6				
				(−1.97)**				
Political stability					−2.8			
					(−1.88)*			
Restraint of corruption						−4.5		
						(−2.51)**		
Democratic accountability							13.6	
							(2.19)**	
Democratic accountability-squared							−12.3	
							(−2.41)**	
Population urban (%)	−0.27	−0.176	−0.215	−0.193	−0.159	−0.217	−0.187	0.082
	(−2.14)**	(−1.14)	(−1.32)	(−1.13)	(−1.00)	(−1.33)	(−1.13)	(0.30)
Population 15–64 (%) a/	−0.49	−0.233	−0.315	−0.241	−0.214	−0.366	−0.293	−0.6
	(−2.49)**	(−1.08)	(−1.39)	(−0.99)	(−.94)	(−1.76)*	(−1.27)	(1.93)*
Population 65+ (%)	−0.59	1.08	1.67	1.82	1.11	1.61	1.99	−0.70
	(−0.78)	(1.32)	(−2.01)**	(−2.07)**	−1.29	(−2.00)**	(−2.33)**	(−0.67)
Initial stunting								−0.55
								(−5.70)***
Number of observations	380	380	383	383	380	383	383	303
Number of countries	81	81	81	81	81	81	81	75
R-squared	0.637	0.428	0.412	0.387	0.410	0.405	0.389	0.064
Ramsey RESET b/ (*p*-Values)	0.001***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.005***

Notes: t-Statistics (in parentheses) are robust to heteroskedasticity and clustering by country.
Stars represent statistical significance at the 10% (*), 5% (**) and 1% (***) levels.
a/ The reference category is the percent of population less than 15 years.
b/ The 2SLS estimates employ the robust Ramsey/Pesaran–Taylor RESET test adapted for instrumental variables estimation (see Schaffer, 2007).

Table 7. *Basic determinants – pathways of influence*

Basic determinant	Stunting	Underlying determinant					
		Access to safe water	Access to sanitation	Female secondary school enrollment	Female-to-male life expectancy ratio	Per capita dietary energy supply	Percent of dietary energy from non-staples
Per capita GDP ($ PPP)	–		+	+		+	+
Governance a/							
Governance index	–	+					
Bureaucratic effectiveness	–	+	+				
Law and order	–	+					
Political stability	–	+			–		+
Restraint of corruption	–				+	–	
Democratic accountability	+/–			+		+	

Note: The designation "–"("+") signifies that the basic determinant has a negative (positive) impact on the underlying determinant. The designation "+/–" signifies that the impact is either positive or negative, depending on the position along a quadratic function.
a/ The governance index and each of its five dimensions were considered individually in separate regressions, with stunting and each of the six underlying determinants as dependent variables (for a total of 36 separate regression equations).

in countries. It does not, however, appear to have an impact on access to safe water or the degree of gender equality, the latter which may be more strongly linked to cultural factors that only change slowly with income.

(b) *Quality of governance*

Turning next to the role of governance, testing rules problems of bias in the coefficient estimates due to endogeneity issues to be unlikely. The instruments employed for testing include indicators of ethnic and religious tensions in countries,[39] the degree of military involvement in politics, the percent of youth in populations (or the "youth bulge")[40] and mortality in the typical age group of politicians and powerful government bureaucrats (40–60 years) (see Table 10). In only one case was an instrument set weak, that for bureaucratic effectiveness, for which the maximal relative IV bias is 20%.[41]

The coefficient on the governance index is negative and significant at the 5% level (Table 6, column 2): better quality of governance in countries serves to reduce child undernutrition, even controlling for income. Given the additive nature of this index, the result indicates that the higher are the levels of the five dimensions of governance as a group, the lower will be child stunting prevalences. But which of the dimensions is contributing to this effect? As seen in columns (3)–(6), the coefficients for the first four indicators of governance—bureaucratic effectiveness, law and order, political stability, and restraint of corruption—are also all negative, consistent with our hypotheses. Democratic accountability (column (7)), by contrast, exhibits a clear non-linear relationship with stunting, serving to reduce it only in countries having relatively high levels of democracy. Because of the inter-correlations between the indicators,[42] we refrain from drawing conclusions from this analysis about their relative strength of impact. However, the results presented here suggest that all five contribute in some way to reductions in child stunting. Note that the pre-post year 2000 testing for structural differences in the coefficient estimates revealed none.

The results on pathways of influence (Table 7) indicate that a key pathway through which governance influences child stunting is by facilitating increased access to safe water and thus improving the quality of health environments. Three dimensions of governance are associated with increased access to safe water: bureaucratic effectiveness, law and order, and political stability. Bureaucratic effectiveness also leads to increased access to sanitation. The results further suggest that democratic accountability serves to enhance women's educational attainment, and political stability increases the quality of the food available in countries, i.e., the percent of the energy available that derives from such foods as meats, fruits and vegetables.

The results are inconclusive with respect to gender equality and national food availabilities. While restraint of corruption appears to have a positive impact on the degree of gender equality, political stability exhibits a negative impact. We do not as yet understand the reason for this relationship, and it is one that warrants further research.[43] Similarly, while democratic accountability shows a positive impact on national food availability, restraint of corruption exhibits a negative impact, perhaps because corruption is a disincentive to food production and imports. Clearly these results raise more questions than they answer and are useful pointers to future research.

Of note, while the regression results for the influence of democratic accountability on child stunting suggest that its effects are only positive at higher levels, those regarding the pathways of influence shed a more affirmative light given positive impacts on both women's education and food supplies.

Governance has no impact on child stunting in the short run according to the first-difference results. This is the case for the overall governance index (see column 8) and the ICRG indicators of all of its dimensions except democratic accountability, the latter for which there is some indication of a positive (unfavorable) effect on stunting.[44]

Note that when we examined the influence of governance employing an alternative set of governance indicators, the Worldwide Governance Indicators (WGI) reported by the World Bank Institute, we found no impact on stunting in either the short or long run. We attribute this to the fact that the WGI indicators are only available from 1996-on, providing a shorter term historical record of data for analysis. In confirmation, when we restrict our analysis using the ICRG indicators to 1996-on, we similarly find no impact on stunting. The WGI should become more useful for understanding the undernutrition impacts of governance as a longer time series becomes available.

7. POLICY PRIORITIES FOR THE POST-MDG ERA

Our analysis gives clear guidance to governments and international development agencies regarding which determinants of child undernutrition should be considered in policy strategies to accelerate reductions in undernutrition in the coming decades. Such strategies should focus on:

- Improving health environments through increasing access to safe water and sanitation. This goal is most likely also achieved with increased access to health care (although we could not evaluate this aspect of health environments here due to data limitations);
- Improving the quality of caring practices for children through increasing women's education and promoting gender equality, including women's empowerment; and
- Increasing food security by ensuring adequate availability of food at the national level and sufficient nutritional quality of that food. While not explored here, actions to ensure that the available food can be accessed by those who need it would surely be helpful as well.

In other words, all of the underlying determinants representing food, health, and care are important. This is a reassuring affirmation of the enduring relevance of the UNICEF conceptual framework.

The analysis also points to the key importance of continuing to foster economic growth and improving the quality of governance in developing countries. As pointed out by Smith and Haddad (2002), our estimates for the basic determinants are only a reflection of the past degree to which the forces of income and governance have been directed at factors that more directly affect child nutritional status, such as the underlying determinants found here to do so. In the case of income, policy makers have a choice as to how increased public resources from income growth are allocated. They can also influence to whom increased household incomes are allocated (whether to the poor or rich) and how households allocate increased incomes, for example, through price and other economic incentives and awareness-raising campaigns. Future reductions in child undernutrition can be accelerated by increased investment of that income in fostering the underlying determinants of child nutrition. In the case of governance, enhanced democratic accountability can foster the necessary political will for increasing investment in the underlying determinants. Bureaucratic effectiveness, law and order,

political stability, and restraint of corruption can all be brought to bear to formulate and implement sound interventions resulting from these investments.

We now turn our focus to the two regions of the developing world where stunting is the highest, South Asia and Sub-Saharan Africa. We then conclude this section with a look at the implications of using stunting *versus* underweight for child undernutrition measurement to guide future policy decisions.

(a) *Priorities for South Asia*

In 1995 the prevalence of child stunting was far higher in South Asia than in any other region of the world (Smith & Haddad, 2000). Since this time it has fallen considerably, and the total reduction since 1970, near 30 percentage points, has been substantial (see Table 1). How did this take place? Figure 4a shows the historical record of progress in increasing the underlying determinants over the period. The determinant that increased the most is access to safe water. There have also been substantial improvements in women's education and in the gender life expectancy ratio in the region. The determinants that have improved the least are the quantity and quality of food available in countries. Figure 4b shows the percentage contribution to the estimated reduction in the stunting prevalence in the region. The factors that contributed most are increased access to safe water and improvements in the gender life expectancy ratio, contributing roughly 30% each. The contribution of access to safe water is mainly due to the huge progress that has been made in this area. That of the life expectancy ratio is due to increases in the ratio in conjunction with the fact that such increases have a particularly powerful impact in South Asia compared to the other developing regions (see Table 3, column (2)).

Looking toward the future, what can be done to further reduce child stunting in the region from its current unacceptable prevalence of 40%? All of the underlying determinants with the exception of access to safe water fall substantially below desirable levels in the region. While continued improvements in women's education and food availabilities are

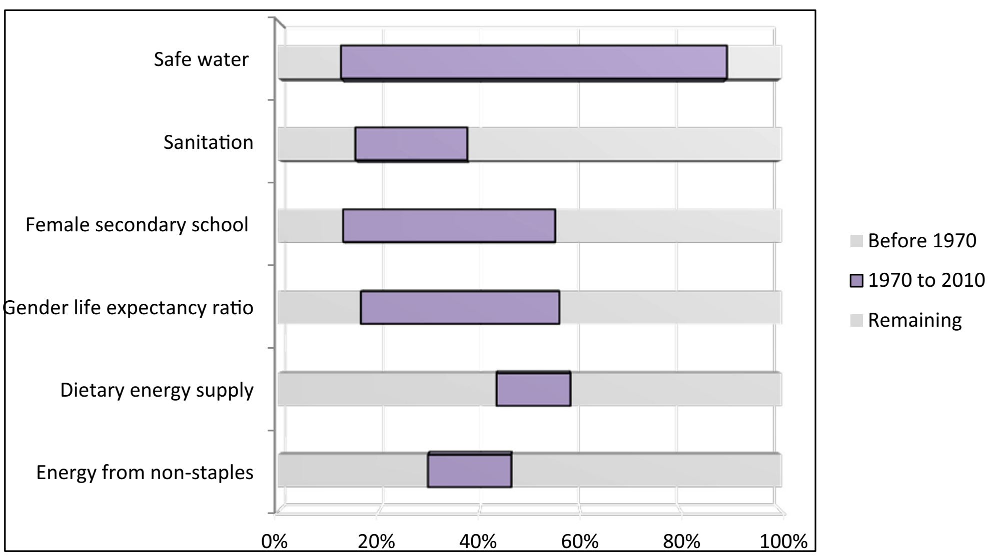

Figure 4a. *South Asia: Increases in underlying determinants, 1970–2010 (On an equivalent scale of 0–100%).*

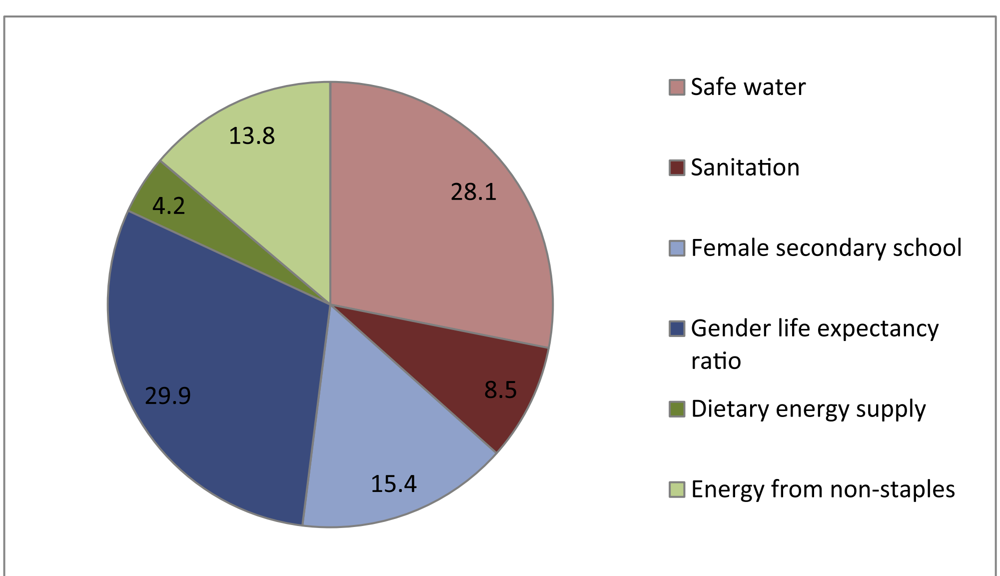

Figure 4b. *South Asia: Contributions of underlying determinants to total estimated reductions in stunting, 1970–2010 (percent).*

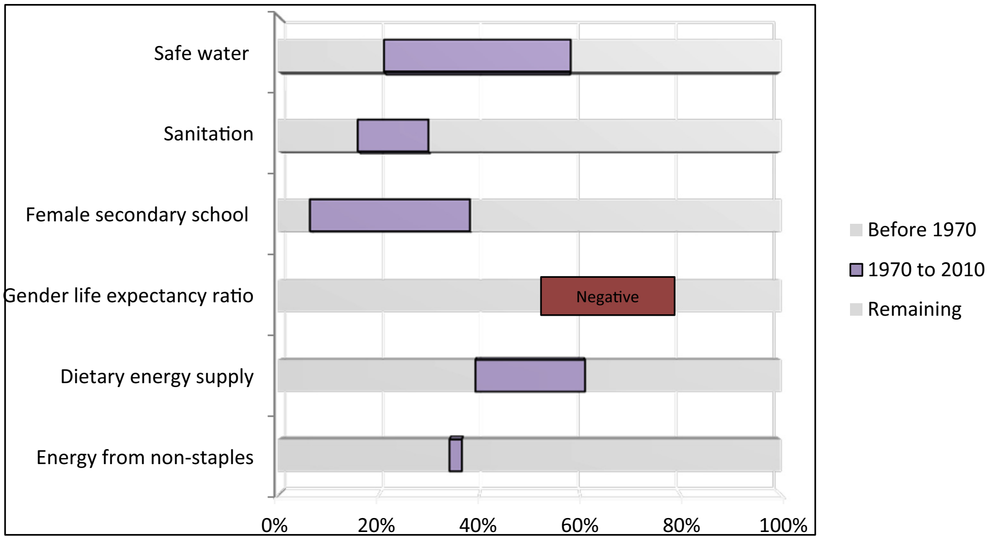

Figure 5a. *Sub-Saharan Africa: Increases in underlying determinants, 1970–2010 (On an equivalent scale of 0–100%).*

needed, three of the determinants should be of particular focus: access to sanitation, dietary diversity of food supplies, and gender equality. The first two should be prioritized because they have quite strong impacts yet are farthest below their desired levels. Only 38% of the population of South Asia has access to sanitation, that is, hygienic disposal of human waste. This is undoubtedly a primary factor leading to the spread of infectious disease and thus harming children's nutritional status regardless of how much food they eat and its quality. Only 40% of the food supply is made up of non-staples, such as meats, fruits and vegetables. The resulting likely poor diet quality must also be addressed to accelerate reductions in child stunting in the coming decades.

The third determinant that should be of particular focus in South Asia, gender equality, is far below its desired level as well, but should also be prioritized because, as the regression results show, it has such a uniquely strong impact on child stunting in the region. Continued improvement in this area would likely greatly accelerate reductions in stunting. According to our estimates, if this determinant alone were to reach its desired level, the stunting prevalence in South Asia would decline by 10 percentage points.

With respect to the basic determinants, South Asia has experienced a more than doubling of its national income since the 1970s. Among the regions, however, it has the second-lowest per-capita GDP. Continued increases in national income are vital for fostering an enabling environment for reducing child stunting in the region. Continued improvements in the quality of governance are also needed, with a particular focus on promoting political stability, the only dimension of governance that is significantly below the developing-country average.

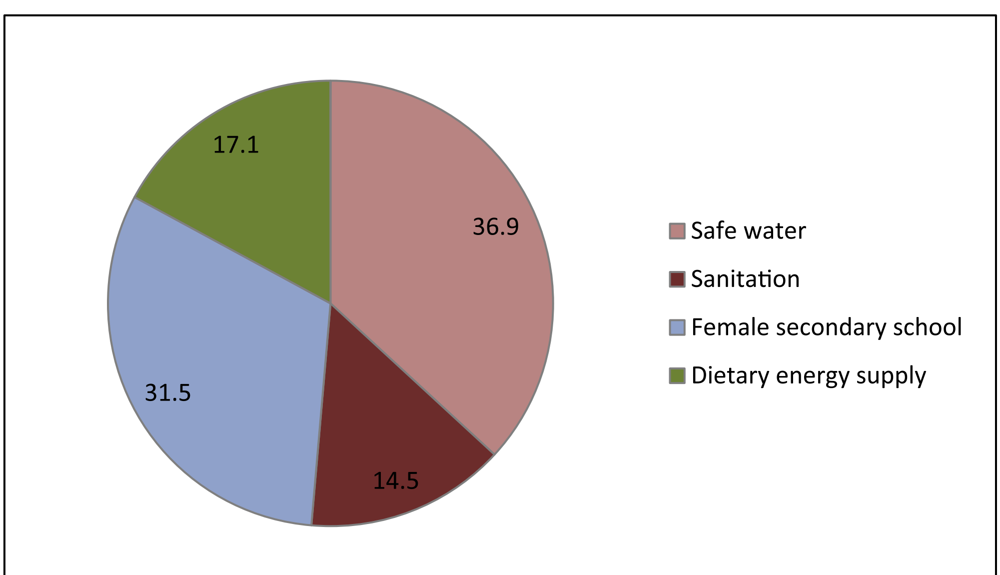

Figure 5b. *Sub-Saharan Africa: Contributions of underlying determinants to total estimated reductions in stunting, 1970–2010 (percent). Note: The estimation results suggest that the degree of gender equality, as measured by the female-to-male life expectancy ratio, and dietary energy from non-staples made no contributions to reductions in stunting, with declines in gender equality in fact hampering further reductions.*

(b) *Priorities for Sub-Saharan Africa*

In Sub-Saharan Africa the prevalence of stunting has fallen very little since 1970, by only six percentage points over the entire 40-year period (Table 1). Figure 5a shows the progress made in increasing the underlying determinants since the 1970s. Here we see that, unlike South Asia, at a regional level there has been little change for most determinants. Progress has been particularly slow in the cases of sanitation, national food availabilities, and the dietary diversity of food supplies. Of note also is that while it was far above that of South Asia in the 1970s, the gender life expectancy ratio has registered a *decline* over time, now being on par with South Asia. The source of this decline—and measures to reverse it—must be investigated further. The largest drop took place over the 1990's, which may be an indication that the HIV/AIDS epidemic is a starting point for investigation. Women are more vulnerable than men to HIV infection, not only for biological reasons but also due to discrimination, gender inequality, and violence (WHO, 2013b).

Figure 5b shows that of the determinants that made a positive contribution to the small estimated decline in child stunting that did take place in Sub-Saharan Africa, improvements in safe water access made the greatest contribution, followed by increases in women's education.

Looking toward the future, what can be done to accelerate reductions in malnutrition in this region where its high prevalence has been stubbornly persistent? Our empirical results point to access to sanitation, women's education, and gender equality as key priority areas. All of the underlying determinants fall substantially below desirable levels in the region, but especially sanitation and women's education. With regard to sanitation, only 31% of the population has access to sanitary waste disposal facilities; yet the regression results show that sanitation is likely to have the greatest strength of impact among all of the underlying determinants considered here. With regard to women's education, only 39% of women have completed a secondary education, and this determinant also has a relatively strong impact. While the dietary diversity of the food supply is very low, the data indicate that this determinant does not have a strong potential, relatively speaking, for inducing major reductions in child stunting in the region. Finally, efforts should be made to stop the erosion of gender equality in the region, which has surely undermined any gains made due to improvements in the other determinants and thereby contributed to the persistence of the region's high stunting rate.

Table 8. *Determinants of child undernutrition—stunting versus underweight*

	Underlying determinants (OLS-Fixed effects)		Basic determinants (Fixed effects)	
	Stunting	Underweight	Stunting (2SLS)	Underweight (OLS)
Underlying determinants				
Access to safe water	−0.112	−0.107		
	(−3.82)***	(−3.83)***		
Access to sanitation	−0.127	−0.084		
	(−3.34)***	(−2.61)***		
Female secondary school enrollment	−0.113	−0.070		
	(−3.84)***	(−3.21)***		
Female-to-male life expectancy ratio	−73.1	−46.9		
	(−4.05)***	(−2.70)***		
Per capita dietary energy supply	−0.0074	−0.0044		
	(−3.35)***	(−2.27)**		
Percent of dietary energy from non-staples	−0.282	−0.220		
	(−2.55)***	(−2.52)**		
Basic determinants a/				
ln(Per capita GDP) ($ PPP)			−19.4	−6.3
			(5.34)***	(−3.81)***
Governance index			−8.3	−5.8
			(−2.56)**	(−1.83)*
Bureaucratic effectiveness			−3.9	−4.2
			(−2.10)**	(−2.26)**
Law and order			−4.6	−0.63
			(−1.97)**	(−0.42)
Political stability			−2.8	−2.0
			(−1.88)*	(−1.55)
Restraint of corruption			−4.5	−2.5
			(−2.51)**	(−1.43)
Democratic accountability			13.6	−0.74
			(−2.19)**	(−0.64)
Democratic accountability-squared			−12.3	
			(−2.41)**	
Number of observations	534	532	383	382
Number of countries	116	117	81	81
R-squared	0.628	0.534	0.426	0.444
Ramsey RESET test (*p*-values)	0.307	0.000***	0.000***	0.000***

Note: Stars represent statistical significance at the 10% (*), 5% (**) and 1% (***) levels.
a/ The governance indicators are entered individually into each regression with the demographic variables controlled for (as in Table 6).

Regarding the basic determinants, Sub-Saharan Africa had the lowest per-capita GDP of all of the developing regions in 2010, and per capita real GDP has increased by only 16% since 1970. Poverty-reducing income growth should be a strong priority in the quest to reduce child stunting. Sub-Saharan Africa scores the worst on the governance index. Among the developing regions it is doing worse than average in the areas of restraint of corruption and bureaucratic effectiveness, with a particularly poor record in the latter. Improvements in these key dimensions of governance will be important for accelerating reductions in child stunting in the region.

(c) *Getting measurement right: stunting versus underweight*

As mentioned above, the measure of child undernutrition on which MDG-1 was formulated is underweight. Stunting has now become the preferred measure. But how much does the choice of stunting over underweight matter? Table 8 documents the differences in our regression results between the two measures. We find that indeed the choice does make a difference when it comes to understanding the relative strengths of impact of the various determinants and, in some cases, even whether some have any impact.

As for stunting, the underweight measure identifies all of the underlying determinants to have statistically significant, negative impacts on child undernutrition. The coefficients on all determinants in the underweight specification are smaller than for stunting, but this is partially because underweight has a far lower sample mean than stunting (32.7% *versus* 17.6%). In terms of the relative strength of impact of the determinants on child undernutrition the main difference we find is for safe water. It is identified to have a far more potent impact relative to the other determinants when underweight is employed, second only to dietary quality, whereas when stunting is employed it is ranked second-to-last among the six determinants.

The differences are starker in the case of the basic determinants. The income elasticity is much lower for underweight than stunting.[45] A 10% increase in income is predicted to lead to a 3.6% decline in undernutrition when underweight is employed *versus* a 6.3% decline when stunting is employed. While all governance indicators have a statistically significant, negative impact on child undernutrition for stunting, only bureaucratic effectiveness does so for underweight.

Clearly, not only does the choice of stunting over underweight make a difference in terms of the levels and trends in child undernutrition, but also in terms of identifying and quantifying the impact of its determinants. The choice of measure thus also makes a difference for identifying priority interventions for reducing undernutrition.

8. CONCLUSIONS

This study has investigated the drivers of past child undernutrition reductions and identified priorities for accelerating reductions in the post-MDG era. It builds on Smith and Haddad (2000) by including more countries and years; employing stunting as its measure of undernutrition; introducing new underlying determinant variables—sanitation and the percent of food supply from non-staples; and exploring the role of governance.

Our findings are as follows:

1. At the all-country level, the three sets of variables that proxy for the underlying determinants (food, care and health environment) have all made strong contributions to the reductions in stunting that took place over the 1970–2010 period. It is important to keep in mind that our findings on the relative contributions of the various underlying determinants to reductions in stunting are based not only on the relative strength of impact of each determinant, but also on how much each changed over the 40-year period. National incomes and the quality of governance have played a key role by facilitating improvements in the underlying determinants. These results are robust to controlling for country fixed effects and take into account endogeneity where it is apparent.
2. Looking forward, a rough ranking of the underlying determinants in terms of their future potency in reducing child stunting is: percent of dietary energy from non-staples (greatest), followed by access to sanitation and women's education. Access to safe water, gender equality, and national food availabilities have the lowest strength of impact, but do not fall far behind women's education.
3. Investments in women's education, increasing gender equality, and in increasing national food availabilities can be expected to have an impact on national stunting rates even in the short run (over roughly five years), while investments in health environments and improving the dietary diversity of food available in countries have their impacts only over longer periods.
4. Our income results are in line with those of Ruel *et al.* (2013) and Headey (2012)—with a long-run stunting-income elasticity of 0.63 and a short run elasticity of 0.17. Income growth reduces child stunting by supporting access to sanitation, women' education, and the quality and quantity of food available in countries. It will continue to be important for stunting reduction in the post-MDG era. While not tested here, its link with stunting is surely stronger if it is poverty-reducing growth.
5. We find clear evidence that improvements in the quality of governance reduce child stunting. The governance analysis is a particularly new contribution to the literature and one that opens up a new field for empirical exploration. As does income, governance works through the underlying determinants. To date, the effects appear to be strongest through improving access to safe water. Water is particularly political, and perhaps the finding reflects this, but more research is needed to explore this pathway. The governance variables seem to take a long time to work through to stunting reduction, suggesting that whatever nutrition interventions themselves can do to improve the micro-governance that surrounds them will be useful.
6. Focusing in on the regions with the highest stunting prevalences, we find the following:
   - For South Asia, while continued improvements in women's education and food availabilities are needed, three of the determinants should be of particular focus: access to sanitation, dietary diversity of the food available in countries, and gender equality.
   - For Sub-Saharan Africa our empirical results point to access to sanitation, women's education, and gender equality as key priority areas.
   - These two regions have the lowest national incomes among all developing regions. Continued income growth will be vital for fostering an enabling environment for reducing stunting.
   - Improving the quality of governance should also be a priority in both regions, with a focus on political stability in South Asia and on bureaucratic effectiveness and restraint of corruption in Sub-Saharan Africa.

7. Substituting underweight for stunting changes our results quite significantly. Changing the international standard child undernutrition indicator makes a difference not only for tracking the levels and trends in undernutrition, but also for identifying priority actions for reducing it in the future.
8. Finally, we find no structural changes in the importance of the determinants pre and post 2000, the onset of the MDGs. The MDGs are thought to have increased ODA shares to Sub- Saharan Africa and to the health sectors and we were interested to test whether this affected the relationship (Haddad, 2013b). Of course many other things happened after 2000, and it will be interesting in future work to explore the pre and post 2008 relationship given the food, fuel and financial disruptions of that year.

Note that national food availability does not feature near the top of the priorities for accelerating undernutrition reductions in either South Asia or Sub-Saharan Africa. This does not reduce the importance of maintaining adequate food supplies, including food production, but simply acknowledges that the scope for it to reduce stunting prevalences is lower than that of the priority underlying determinants we have identified. Just maintaining food supplies is going to require an enormous collective effort in the coming years, so reducing investment in agriculture is not recommended. Food supply is arguably the underlying determinant most at risk of disruption from climate change, and considerable effort needs to be expended to maintain production in the face of these increased uncertainties. Further, we need to keep in mind that food supplies are a necessary, but not sufficient, condition for food security and the link between stunting and food supplies is dependent on whether children's households have access to that food.

What do our results imply for the *Lancet* 2013 conclusions? First, that the underlying determinants are powerful drivers of stunting reduction—they need to be accelerated rapidly. They still account for a large percentage of public spending—much more than that spent on nutrition-specific and nutrition-sensitive interventions—and the nutrition community must not lose its focus on them. Of course investments in the underlying determinants include the small minority of spending on them that is nutrition-sensitive, i.e., investments in these areas that attempt to do something explicit to improve nutrition outcomes. Unfortunately we cannot break out the underlying determinants in this way, but with improved data on nutrition investment such an analysis should be possible and illuminating.

Second, the analysis also affirms the importance of continued income growth and strong governance as key components of an enabling environment for nutrition improvements. Interestingly, the results suggest that different dimensions of governance are important for different underlying determinants—a constant reminder that when it comes to accelerating improvements in nutrition status, complexity is something to be recognized and navigated, not ignored.

Finally, impact evaluations such as randomized controlled trials, which have traditionally been primary sources of evidence in the physical sciences, are important ways to illuminate key action points, but it is difficult and misleading to construct an overall picture by relying solely on them (Pinstrup-Andersen, 2013). This analysis shows the importance of occasionally taking a 'big picture" view of nutrition, drawing on the wide range of knowledge that can be brought to bear in building the evidence base for accelerating reductions in undernutrition and thus preventing the deaths, squandering of human potential, and impeded development stemming from it.

NOTES

1. One of the main reasons for the shift is that underweight (weight for age) fails to identify the increasing number of cases of undernutrition characterized by both overweight and short stature (de Onis, Blössner, & Borghi, 2011).

2. Specifically, we looked at Freedom House indicators of political rights and civil liberties (Freedom House, 2013).

3. The definitions and descriptions of each dimension given here are from World Bank (2013c) and PRS (2013). Note that the five dimensions essentially correspond to those of the Worldwide Governance Indicators (World Bank, 2013b), with the exception that the concepts of "government effectiveness" and "regulatory quality" are combined into one: "bureaucratic effectiveness".

4. The 132 countries are those classified as "developing" (typically low and middle income) by the World Bank as of 2012 (see World Bank, 2012) and with populations greater than 165,000.

5. While the focus for actions and policies to reduce childhood undernutrition is shifting to under-twos, the under-five group, unfortunately, continues to be the predominant standard for measurement.

6. Where data are reported using the 1977 NCHS/WHO reference they are translated into the WHO 2006 reference equivalent using the algorithm provided in Yang and de Onis (2008). Where they are reported for age groups other than 0–5 (12% of the data points), they are converted to under-five-year-old equivalents based on the technique employed in UNICEF (2010).

7. The goal was to match on the exact year of the stunting data as per our empirical strategy (see Eqns. (1) and (3) in Section 4). In the majority of cases such exact matching was possible. Where it was not, then the closest matching year available within three years was employed. A small number of observations are based on predicted values for at most two of the independent variables, where predictions are undertaken using Ordinary Least Squares regression with the non-missing independent variables as predictors. The independent variable for which the most values are predicted in this manner is female secondary enrollments (6%).

8. The only available indicator is FAO's measure of the prevalence of undernourishment in countries. This measure is based on national food supply statistics, however and not survey-based estimates of household or individual food consumption (Smith, Alderman, & Aduayom, 2006). Such a survey-based measure may be available in the future if appropriate food data, including data on food consumed outside of the home, are collected in more nationally representative Household Consumption and Expenditure Surveys (Smith, 2013; Smith, Dupriez, & Troubat, 2013). See Carletto, Zezza, and Banerjee (2012) for a recent review of currently available food security indicators.

9. We recognize that enough food of adequate quality at the national level is a necessary, but not sufficient, condition for achieving household food security. We do not include direct indicators of household food security in this analysis due to lack of data.

10. See Cafiero (2013) for measurement details and a discussion of reliability issues.

11. At the time the data set for this study was compiled (September 2012–March 2013) the FAOSTAT database only contained data up to 2009. Following the " +/−3 rule" used for inclusion of observations in the study, 2009 data were used for all 2010, 2011 and 2012 observations (11% of the observations).

12. A small number of cases for which data were not available ($N = 35/534$) were predicted using an alternative method than that used for the other variables. Data on various education indicators from the World Development Indicators (World Bank, 2013b) were used to predict female gross secondary enrollments employing OLS regression under the conditions that the R-squared be at least 0.75 and the number of observations $\geqslant 50$.

13. There may be some concern that changes over the last decades in the female-to-male life expectancy ratio are only a reflection of improvements in adult women's health. If this were the case, the finding of an impact of the indicator on child stunting would merely be a reflection of the fact that women with better health are less likely to have low birth weight children and provide higher quality caring practices for their children. For the developing countries as a whole, the ratio itself has increased by about 2% during 1970–2010 (see Table 5 below). Both female and male life expectancy increased considerably over this period: female life expectancy increased by 13.5 years (24%) and male life expectancy by 11.7 years (22%). The increases have thus not been solely a reflection of improvements in women's health. The concern that changes in the life expectancy ratio are only a reflection of women's health status is also allayed by the fact that gender differences in life expectancy are strongly influenced by gender disparities in *child* (rather than adolescent and adult) mortality rates (World Bank, 2007, chap. 3). Indeed our data set gives evidence of a strong correlation between the gender life expectancy ratio and the ratio of male-to-female infant mortality rates ($r = 0.529$, $p = 0.000$) and under-five mortality rates ($r = 0.628, p = 0.000$). Note that we do not use the sex ratio at birth (SRB), which would clearly be no reflection of current female health status, as our indicator of gender inequalities for two reasons. First, while recent changes in technology have made female-biased sex selection more common, leading to increased SRBs (more males born relative to females) in some countries (e.g., China and Azerbaijan) (UNFPA, 2012), for the large majority of countries in our sample there has been no change in this indicator since 1970. Thus, use of the SRB would not be appropriate for this study, which relies on panel data analysis. Second, while the reasons are not yet well understood, globally, higher birth rates of males relative to females are associated with *better* health conditions for reasons having nothing to do with gender inequalities and sex discrimination (Dama, 2011, 2013; Thomas, Daoust, Elguero, & Raymond, 2012). Based on this information, we would expect the SRB to be *negatively* associated with stunting, contrary to the hypothesis of greater gender inequality being associated with greater stunting. In fact in our data the correlation between stunting and the SRB is negative (-0.224, $p = 0.000$).

14. The specific indicators referred to are the percent of the total labor force that is female and the ratio of female-to-male labor force participation rates.

15. The indicator "Percent of population with access to health services" was reported regularly in UNDP Human Development Reports up to 2000 and in UNICEF's State of the World's Children reports up to 1998, but not thereafter due to lack of reliable data. Data for some countries are collected as part of Demographic and Health Surveys, but not for sufficient countries and years to allow matching with our data set.

16. The sanitation data from this source are from the World Development Indicators (World Bank, 2013d), the original source being WHO/UNICEF (2013).

17. The actual names of the ICRG indicators are: Bureaucracy quality, law and order, government stability, corruption, and democratic accountability.

18. Given the unbalanced panel, it is not appropriate to include a time trend or period dummy variables in this equation (for example, one for each decade). This is because any particular year or group of years is not available for all countries in the study.

19. While we acknowledge that the demographic control variables specified in Eqns. (2) and (3) may be endogenous to child stunting (especially the percent of the population 0–14 years old), we only test for the endogeneity of the main determinants of interest.

20. Note also that we only use instruments that are both individually and jointly significant in the first stage.

21. The test is defined as the difference of two Sargan–Hansen statistics, one for the equation where the potentially endogenous regressor is treated as endogenous, and one for the equation where it is treated as exogenous. The reported test statistic we specify is robust to heteroskedasticity and within-country correlation.

22. Five observations were dropped from the underlying-determinants analysis and two from the basic-determinants analysis.

23. In the case of per-capita dietary energy supply the chi-squared p-value is 0.056, just barely passing the test (almost significant at the 5% level). However a second set of instruments yields a p-value of 0.138 (see Table 10).

24. Of note is that in some cases the number of observations is substantially lower than the total for underlying-determinants analysis due to lack of matching data for the instruments. This is the case for female secondary enrollments and the female-to-male life expectancy ratio.

25. A formal Hausman test for random *versus* fixed effects rules in favor of the later ($p = 0.001$).

26. This index is calculated using Principal Components Analysis. The first principal component, for which all three indicators enter positively, is employed.

27. Our goal in identifying regional differences was to test whether, for each region individually, any of the determinant coefficients differ significantly and substantially from those of the other regions as a group. For each region, we added six interaction terms to the base fixed-effects regression, one for each determinant interacted with a regional dummy variable. Regressions were subsequently run until only interaction terms that were statistically significant, if any, remained. For verification purposes, for any region with a determinant identified to have a coefficient significantly different from the other regions, we then ran the base regression only for the region's own data points. If the coefficient was verified as strongly different from that of the other regions as a group, we then considered the difference to be significant and substantial. The results presented in column (2) of Table 3 represent estimation of the base fixed-effects equation for the entire sample ($N = 534$) with only the regional interaction terms having significant and substantially different coefficients identified in this way included.

28. While the coefficient on the log of the life expectancy ratio has low statistical significance (being significant at the 1% level for a two-tailed test, though at the 5% level for a one-tailed test), because the size of the coefficient is so large and the finding is consistent with previous empirical work (see Smith *et al.*, 2003 and studies cited therein), we consider the estimate to be practically important from a policy perspective.

29. Examining the data from the SSA countries separately ($N = 202$), we find that pre-2000 dietary energy supply has a significant negative impact on child stunting but that dietary energy from non-staples has no impact.

The post-2000 data exhibit the opposite: dietary energy supply has no impact on child stunting, but dietary energy from non-staples has a small, negative impact. Note however that the latter conclusion is based on weak statistical significance (the t-statistic of the coefficient on the post-year-2000 dummy variable is 1.69 ($p = 0.099$)).

30. This model is preferred over that without trend fixed effects given the very high correlation between these effects and the stunting prevalences predicted by the model (−0.86).

31. Using safe water (safew) as an example, the elasticities are calculated as:

$$\frac{\partial stunting}{\partial safew} * \frac{mean(safew)}{mean(stunting)} = -0.112 * 73.0/32.7.$$

For the gender life expectancy ratio the elasticity is calculated for the unlogged ratio.

32. See notes to Table 4.

33. This procedure is similar to that undertaken in the estimation of "population attributable risk" (common in epidemiology) in which information on the risk of contracting a disease (such as lung cancer) from exposure to risk factors (such as smoking) is combined with information on the prevalence of the risk factor to determine the number of cases of the disease that are associated with the risk factor (Kahn & Sempos, 1989).

34. Despite the omission of this variable we are nevertheless confident that the coefficient estimates of the included variables do not suffer from omitted variables bias given the results of our instrumental variables tests.

35. Such mis-specification is indicated even after testing and correcting for endogeneity, as detailed below. Tests for interactions between income and governance showed none to be significant, and any non-linearities detected are taken into account in the analysis.

36. Such a pattern of higher 2SLS than OLS estimates have been found in other studies of the relationship between income and health and nutrition outcomes as well (e.g., Chin, 2010; Pritchett & Summers, 1996). Of note is that we did not find any evidence of bias when looking at the impact of income on the individual underlying determinants or on underweight (Section 7), which would suggest that measurement error in income may not be at issue.

37. This value is derived from the coefficient on lnGDP in Table 6, column (2). It is calculated as −19.4*10/30.6.

38. This value is derived from the coefficient on lnGDP in Table 6, column (8). It is calculated as −5.3*10/30.6.

39. Use of this indicator is inspired by the use of "ethnolinguistic fractionalization" as a governance instrument in previous studies (e.g., Mauro, 1995).

40. Employed by Barbonnier, Wagner, and Brugger (2011).

41. In the case of political stability the test results are ambiguous. While the endogeneity test is passed for the $N = 383$ study sample (which is restricted to data points for which the GDP instruments are available), it is not for a slightly larger sample ($p = 0.044$) (see Table 10).

42. The highest correlation between any of the five indicators is 0.37 (between Restraint of corruption and Law and Order). Many of the correlations are zero, for example, political stability is only correlated positively with Law and Order.

43. We acknowledge the possibility that this finding may be a reflection of demographic changes unrelated to gender equality more broadly in that political instability is often more highly associated with male deaths than female deaths.

44. The t-statistic on the positive regression coefficient in the first-difference equation is 2.04 ($p = 0.044$).

45. Note the income is not found to be endogenous when underweight is used as the measure of undernutrition and thus OLS estimates are presented.

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APPENDIX

Table 9. *Regional, country, and population coverage of the study*

Region	Number of countries	Number of observations	Percent of developing countries covered	Share of developing-country population
Underlying determinants analysis				
South Asia	8	40	100	100.0
Sub-Saharan Africa	44	202	95.7	96.6
East Asia and the Pacific	15	72	88.2	99.9
Middle East and North Africa	13	61	100	100.0
Latin America and the Caribbean	22	115	88.0	97.9
Europe and Central Asia (developing)	14	44	60.9	46.6
Total	116	534	87.9	95.5
Basic determinants analysis				
South Asia	4	22	50.0	96.0
Sub-Saharan Africa	30	143	65.2	88.7
East Asia and the Pacific	8	41	47.1	95.1
Middle East and North Africa	10	45	77	91.3
Latin America and the Caribbean	22	110	88.0	97.9
Europe and Central Asia (developing)	7	22	30.4	32.8
Total	81	383	61.4	90.1

Note: All population percentages are for 2010 and represent the percent among only the developing countries with populations greater than 165,000.

Table 10. *Instrumental variables and test statistics for endogeneity tests*

Determinant/ Instrument set	Source	Weak instrument test: Kleibergen-Paap rk Wald *F*-stat	Weak instrument test: Maximal IV relative bias	Overidentification test: Hansen J-statistic (chi-sq *p*-value)	Endogeneity test: Robust equivalent of Durbin–Wu–Hausman test (chi-sq *p*-value)	*N*
Underlying determinants						
Access to safe water (%)						
Renewable internal freshwater resources per capita (cubic meters)***	WDI a/	10.5	10%	0.218	0.698	454
Temperature (°C)***	Dell *et al.*, (2012)					
Interaction of above indicators**						
Access to sanitation (%)						
Annual freshwater withdrawals, total (% of internal resources)*	WDI	32.7	5%	0.280	0.513	371
Health expenditure per capita, PPP (constant 2005 int'$)***	WDI					
Interaction of above indicators***						
Female secondary school enrollment (% gross)						
Secondary education, teachers (per capita)***	WDI	14.4	5%	0.423	0.218	354
Pupil-teacher ratio, secondary***	WDI					
Secondary education, teachers (% female)***	WDI					
Female-to-male life expectancy ratio						
Proportion of seats held by women in national parliaments (%)*	WDI	7.8	20%	0.285	0.982	290
Female age at first marriage (years)**	UNPD (2013)					
Female death rate among 40–44 year olds***	UNPD (2013)					
Per capita dietary energy supply						
Arable land (% of land area)***	WDI	158	5%	0.188	0.056	504
Cereal yield (kg per hectare)***	WDI					
	WDI					
Agricultural land (% of land area)**	WDI	14.4	5%	0.107	0.138	504
Cereal yield (kg per hectare)***	WDI					
Trade (% of GDP)*	WDI					
Dietary energy from non-staples (%)						
Share of merchandise exports at current PPPs***	PWT (2013)	12.5	10%	0.405	0.095	450
Share of merchandise imports at current PPPs***	PWT (2013)					
Merchandise trade (% of GDP)***	WDI					
Meat imports per capita***	FAOSTAT (2013)					
Telephone lines (per 100 people)***	WDI					

(*continued on next page*)

Table 10 (*continued*)

Determinant/ Instrument set	Source	Weak instrument test		Overidentification test	Endogeneity test	N
		Kleiberger-Paap rk Wald F-stat	Maximal IV relative bias	Hansen J-statistic (chi-sq p-value)	Robust equivalent of Durbin–Wu–Hausman test (chi-sq p-value)	
Basic determinants						
ln(Per capita GDP) (US$ PPP)						
Real investment share of GDP***	PWT (2013)	15.6–18.9	5%	0.174–0.187	0.005–0.017	383
Money and quasi money (M2) as% of GDP***	WDI					
Cereal yield (kg per hectare)**	WDI					
Bureaucratic effectiveness						
Ethnic tensions***	PRS (2013)	8.4	20%	0.576	0.129	405
Military in politics***	PRS (2013)					
Male death rate minus female death rate in 55–59 age group**	UNPD (2013)					
Female death rate: 40–44 year olds***	UNPD (2013)					
Law and order						
Ethnic tensions***	PRS (2013)	24.9	5%	0.111	0.093	405
Military in politics***	PRS (2013)					
Religious tensions**	PRS (2013)					
Male death rate minus female death rate in 40–44 age group**	UNPD (2013)					
Political stability						
Ethnic tensions***	PRS (2013)	12.2	10%	0.786	0.044	400
Male death rate: 40–44 year olds***	UNPD (2013)					
Female death rate: 50–55 year olds*	UNPD (2013)					
Ethnic tensions***	PRS (2013)	12.8	10%	0.681	0.136	383
Male death rate: 40–44 year olds***	UNPD (2013)					
Female death rate: 50–55 year olds**	UNPD (2013)					
Restraint of corruption						
Ethnic tensions**	RPS (2013)	10.9	10%	0.735	0.104	405
Military in politics***	PRS (2013)					
Religious tensions***	PRS (2013)					
Male youth bulge** b/	UNPD (2013)					
Male death rate: 55–59 year olds***	UNPD (2013)					
Democratic accountability						
Military in politics***	PRS (2013)	18.0	5%	0.608	0.143	405
Military in politics-squared***	PRS (2013)					
Male death rate: 55–59 year olds***	UNPD (2013)					

Note: Stars indicate statistical significance at the 10%(*), 5%(**) and 1%(***) levels in (first-stage) regressions with the instruments as independent variables and the determinants as dependent variables.
a/ World Development Indicators (World Bank 2013b).
b/ Percent of male population in the 15–29 age group.