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# Developmental Drivers of Nutritional Change: A Cross-Country Analysis

DEREK D. HEADEY *
*International Food Policy Research Institute (IFPRI), Addis Ababa, Ethiopia*

**Summary.** — We utilize a rich cross-country data set to understand within-country changes in nutrition, with a focus on the role of general developmental factors. We find that economic growth is a strong predictor of nutritional performance, as is growth in food production, although only in more food insecure countries. We find no evidence that infrastructure is directly important, but greater asset ownership, improved access to health services, higher rates of female secondary education, and lower fertility rates, are all strong predictors of improvements in nutrition. We show that national success stories are largely consistent with these findings.


*Key words* — malnutrition, economic growth, agriculture, poverty, health, female education, fertility rates

"*Interventions outside the nutrition sector—indeed, even outside the health sector—can have profound effects on reducing child malnutrition. Indeed, it might be argued that, in the medium to long run, non-nutritional interventions, such as improving agricultural productivity, expanding female schooling, and bringing piped water and electricity to rural areas, might have larger effects on the reduction of child malnutrition than nutritional supplementation or fortification programs.*" Anil Deolalikar (2008).

## 1. INTRODUCTION

The past decade or so has witnessed a remarkable surge of interest in nutrition and development. On the research side there is now abundant evidence that the reduction of malnutrition—including its less visible forms, such as stunting or micronutrient deficiencies—is not only a valid indicator of current deprivation, but also an important predictor of longer term social, physical, and economic outcomes. Malnutrition is associated with 30% of infant deaths; is the single largest factor contributing to the global burden of disease; has adverse effects on school attendance, school performance, and cognitive capacity; and reduces adult labor productivity and wage earnings, as well as overall economic growth, and even adult happiness. [1] On the policy side, numerous international initiatives have placed high priority on malnutrition. United Nation's Millennium Development Goals (MDGs) include halving child malnutrition as a key goal. Among the Copenhagen Consensus' list of top 10 priorities for international development interventions, nutrition-specific interventions featured five times. [2] And there are now sizeable international initiatives with the specific aim of scaling up nutrition efforts in developing countries. [3]

Yet despite this growing consensus that reducing childhood malnutrition is a critically important development goal, there is less consensus on the best way forward. A considerable body of research in the nutrition and public health fields has focused on evaluating the impact of nutrition-specific interventions, such as food, mineral, and vitamin supplements or training and education programs. The standard tools in these evaluations are randomized control trials to establish internal validity and systematic reviews to explore external validity (see, for example, Bhutta *et al.*, 2008). Many of these interventions have been shown to be very cost effective, and have therefore been advocated as important components of nutrition strategies (Horton, Alderman, & Rivera, 2008). Yet as the above quote from Deolalikar's (2008) review of the Copenhagen Consensus recommendations suggests, interventions outside the nutrition sector could conceivably be more cost-effective over the medium to longer term, especially if these interventions could be made more "nutrition-sensitive", and if such interventions yield substantial non-nutrition benefits, such as economic growth. A more recent Copenhagen Consensus paper also argued that agricultural development will be essential for reducing malnutrition in the coming decades (Hoddinott, Rosegrant, & Torero, 2012). More generally, the fact that malnutrition is a highly multifaceted socio-economic problem could suggest that only sustained economic development can eliminate undernutrition.

In this paper, we explore the role of some of the "non-nutrition" factors that might influence nutrition outcomes. While this is a broad research agenda that could be addressed with a number of tools, this study focuses on some specific questions and mostly uses one specific tool, a dynamic cross-country analysis. The specific questions we ask are threefold. First, what impact does economic growth typically have on reducing chronic malnutrition (stunting) in developing countries? Second, what impacts do agricultural and non-agricultural growth typically have on reducing stunting? Third, what impacts do social sector investments have on reducing stunting? To address these three questions we primarily rely on a dynamic cross-country analysis that explores the extent to which *changes* in explanatory variables predict *changes* in stunting.

Given that there are several existing studies with similar objectives and methods, it behooves us to outline how this study extends previous research. First, as the previous paragraph suggested, we adopt a more dynamic approach. Previous cross-country studies of malnutrition such as Smith and Haddad (2000, 2002) and Webb and Block (2010) have explored cross-sectional variation in malnutrition rates, albeit

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with panel data sets that control for country level fixed effects.[4] Similarly, most household level studies of malnutrition rely on cross-sectional variation to explore determinants of nutrition. While both types of studies are insightful, inferences drawn from a cross-sectional sample are constrained to a long run interpretation of nutritional change. In other words, at a given point in time, any social, economic, or nutritional differences that exist between a rich country and poor countries are differences that have emerged over the course of history. Hence an analysis of these "long run" differences does not tell us whether economic growth over a decade or two would suffice to halve malnutrition prevalence (i.e., thus achieving MDG-1), or whether recent surges in agricultural, educational, health, and infrastructural investments are likely to reduce malnutrition over the next decade or so. Webb and Block also acknowledge this (2010), and give examples in which within-country relationships between nutrition and economic growth are far from linear.[5] A related problem with pooled cross-sectional regressions is that they are also more vulnerable to endogeneity biases, even with the use of country fixed effects. For these reasons the majority of cross-country econometric analyses have moved away from static models to more dynamic regression techniques. An analogous example of this shift is a recent paper on growth and poverty linkages by Christiaensen *et al*. (2011). These methodological issues are discussed in more detail in Section 2.

In addition to shifting toward somewhat more appropriate statistical tests, we also broaden the scope of the analysis. In Section 3 we start by re-testing linkages between general economic growth and nutrition (as in Heltberg, 2010), but we also examine whether there is a special role for specific productive sectors, particularly for agriculture. This heightened focus on agriculture is topical given its well established importance for poverty reduction, its obvious connections to food security, and recent research advocating the importance of agricultural interventions for improving nutrition outcomes (Fan & Pandya-Lorch, 2012; Hoddinott, Rosegrant, & Torero, 2012; Webb & Block, 2010). In Section 4 we also explore potential "social sector" drivers of nutritional change using indicators available in the Demographic Health Surveys. Again, such research is topical given recent research on the potential developmental benefits of female education (King, Klasen, & Porter, 2008), family planning (Kohler, 2012) and other Millennium Development Goals (such as improved sanitation and water supply).

Finally, while we rely solely on statistical tests in Sections 3 and 4, Section 5 borrows the more inductive analysis of "growth accelerations" pioneered by Hausman, Pritchett, and Rodrik (2005) in the economic growth literature. Specifically, we examine the most rapid episodes of nutritional change in our sample to see whether these experiences are consistent with our formal econometric results. This approach falls short of analyzing these success stories in any depth; instead, we have the more modest goals of testing for consistency, exploring heterogeneity across country experiences, and identifying important questions for future research.

While we believe this triangulation of new data and new methods offers some additional value to the existing literature, we should also flag some important caveats. First, in the economics literature, at least, there are well known limitations of cross-country analyses, as many critiques attest (for example, Durlauf, Johnson, & Temple, 2005). Second, while the dataset we use is quite rich, it remains challenging to test some specific hypotheses, particularly as they relate to agriculture-nutrition linkages. Finally, while we believe some of our results may inform the topical question of which economic and social sector developments might be most effective in reducing malnutrition (e.g., Hoddinott *et al*., 2012), our study says nothing about either the explicit costs of potential interventions, or the political obstacles to reallocating more resources to those economic and social sectors that are most likely to substantially reduce malnutrition (e.g., Acosta & Fanzo, 2012). We leave that challenging task to future research.

## 2. HYPOTHESES, DATA, AND ESTIMATION ISSUES

This section outlines some key hypotheses with respect to the impact of economic growth and other socioeconomic factors on nutrition outcomes, then turns to data issues, and finally outlines an estimation strategy.

### (a) *Hypotheses*

Nutrition outcomes are the result of a very complex causal process. As a means of expressing this complexity in a parsimonious way, the well-known UNICEF (1990) framework clearly emphasizes both the food and non-food determinants of nutrition, as well as different steps in the causal chain. At a proximate level, nutrition outcomes are obviously determined by food intake (macro and micronutrients), yet both appetite and the absorption of nutrients are also substantially affected by health status. Going one step deeper, the quality of diets and health outcomes are strongly influenced by economic status, education, feeding practices, tastes, infrastructure, location, demographic factors (number of children, birth spacing, maternal age), provision of government services, and environmental factors. And going even further, these intermediate outcomes are affected by culture, institutions, and political economy factors. For child malnutrition an added complexity is that it is now rigorously documented that growth faltering occurs most significantly in the first 1000 days of life (Victora, de Onis, Curi Hallal, Blössner & Shrimpton, 2009), including in utero, the first few months of almost exclusive breastfeeding, and after the introduction of solid foods (typically at 6 months of age). This finding clearly has important implications for the demographic targeting of both nutrition-specific and nutrition-sensitive interventions.

The UNICEF model and others like it are useful for identifying a broad list of social and economic factors of potential importance for nutrition, but existing statistical analyses also shed insights as to which factors typically present strong associations with nutrition outcomes. Our reading of the literature suggests that four broad factors consistently emerge as relatively robust determinants of nutrition from survey-based data. We qualify these claims by noting that systematically reviewing the entire nutrition literature would be a major project in itself.

First, household economic status—measured as either household income, expenditure, or assets—quite typically emerges as a robust cross-sectional correlate of nutrition outcomes (Haddad, Alderman, Appleton, Song & Yohannes, 2003).[6] Economic studies also typically suggest that agricultural income is particularly important for the world's poor, most of whom are rural (Bezemer & Headey, 2008; World Bank, 2008). However, there are several potential linkages between income, agricultural production, and nutrition outcomes (Headey, Chiu, & Kadiyala, 2012; Hoddinott, 2011). First, higher incomes raise expenditure levels on food, thereby increasing the quality and quantity of diets. With respect to nutrition, individual level dietary diversity indicators have been shown to be robust predictors of childhood malnutrition outcomes (Arimond & Ruel, 2006). Second, higher incomes raise expenditures on nutrition-relevant non-food expenditures, such as health, sanitation, electricity, water, and housing quality. Third, agricultural growth can promote growth in other sectors (e.g., local non-farm growth) and growth in food production can raise real incomes for the poor by reducing food prices (Diao, Hazell, & Thurlow, 2010). On the other hand, agricultural production is often greatly constrained by volatility (especially rainfed farming) and could yield limited benefits to the poor, especially if land inequality is high.

A second factor that quite consistently emerges from household analyses is maternal education, although one typically observes that only secondary and tertiary schooling tend to be associated with better nutrition outcomes (Behrman & Wolfe, 1984). Moreover, it is not precisely clear what the mechanisms are by which maternal schooling improves nutrition (Webb & Block, 2004).

A third factor strongly supported by theories of nutrition is health. However, health factors are measured in a variety of ways. Controlling for child age, vaccinations against common diseases often bear some correlation with anthropometric indicators. Access to pre-natal, peri-natal, and post-natal care are common enough variables, and have been found significant in some studies. Exposure to diarrhea and other diseases is widely measured and sometimes yields a negative coefficient as well.

Finally, various demographic indicators consistently emerge as important determinants of malnutrition (for example, Dewey & Cohen, 2007; Paul *et al.*, 2011; Rutstein, 2008). Several variables regularly found in survey-based regressions—such as mother's current age, mother's age at marriage, birth order, and birth spacing—are closely correlated with overall fertility rates, and therefore relevant to family planning interventions. One caveat here is that fertility rates are themselves strongly affected by both household income and female education (and labor force participation), which provides some difficulties in disentangling causality. That said, recent analyses of exogenous infertility shocks in India and Latin America uncovered sizeable nutritional gains to having fewer children (Aguero & Marks, 2008; Jensen, 2012).

Many other variables commonly enter both household and national regression estimates, but few are consistently significant. These include infrastructure variables such as piped water, sanitation facilities, electricity, and road infrastructure variables. We find that these variables are consistent in some studies, but not so in others (some examples include Alderman, Hoogeveen, & Rossi, 2005; Christiaensen & Alderman, 2004; Rajaram, Zottarelli, & Sunil, 2007; Sahn & Alderman, 1997). Various factors could explain this. Measurement problems could be prevalent in some cases: piped water may be a poor proxy for water quality, and sanitation a poor proxy for general hygiene (Smith & Haddad, 2002). Some variables may have age-specific effects not accounted for (Sahn & Alderman, 1997), or other specification problems may be present. Or it could be that these variables are simply less important or more indirectly related to nutrition outcomes than the other factors mentioned above, with linkages to nutrition that are more indirect. [7]

The broad factors listed above can broadly be characterized into those pertaining to productive sectors (overall GDP growth, but also growth in agricultural and non-agricultural sectors), and social and infrastructural variables (health, education, demography, infrastructure). Assessing this broad range of factors therefore requires considerable data collection efforts, as well as the construction of different types of datasets.

### (b) *Data and measurement issues*

In this study we have collated an unusually large and rich dataset on malnutrition and a large number of potential determinants (of particular benefit is the online availability of country level data from Demographic Health Surveys). More details of all the variables used in this study are presented in Table 1, while more specific measurement issues are discussed in the text below.

Existing studies have found different growth-nutrition elasticities depending on whether underweight prevalence (weight for age), wasting prevalence (weight for height), or stunting prevalence (height for age) is used as the dependent variable. The choice of dependent variable therefore appears to produce different statistical results, but the choice is not arbitrary, as these indicators represent different physiological processes. Conceptually, weight for height captures acute malnutrition, particularly short term exposure to inadequate nutrient intake, disease, or a combination of the two. In contrast, height for age is the best measure of the cumulative effects of various nutrition processes over time. Weight for age is the product of weight for height and height for age, and hence rather ambiguously combines the latter two indicators. Linking back to the aim of these tests, which is to test the effects of economic growth in the medium term (e.g., 5–10 years), childhood stunting (less than two standard deviations below international norms) is therefore the preferred measure of malnutrition in a conceptual sense. [8]

Ideally, it would also be informative to study the determinants of adult malnutrition. However, adult malnutrition is more typically measured by body mass than by height, such that it is conceptually rather different to stunting. Adult h also have more complex dynamics given that heights are essentially determined in childhood. Nevertheless, for both underweight and low BMI prevalence, the core tests on stunting prevalence are replicated as a sensitivity analysis, and these tests are included in Appendix B.

With regard to data sources, much of our data on malnutrition stems from the Demographic Health Survey's (DHS, 2010), which also includes data on some other important indicators, including: an asset-based extreme poverty measure (the percentage of households who do not own any of the measured assets); fertility rates; and access rates to improved water, sanitation, electricity, medically attended births, vaccinations, and secondary and tertiary education (for adult women). These data are combined with macroeconomic indicators such as national accounts data from *World Development Indicators* (World Bank, 2011), while agricultural and non-agricultural employment data are obtained from the Food and Agriculture Organization (FAO, 2010).

Lastly, there are two important characteristics of this data set. First, for most of the tests conducted the indicators for India are reported at the state level rather than the country level. While the decision to only disaggregate Indian data may seem somewhat arbitrary, there are several good reasons for doing so. First, India accounts for around one-third of the global population of malnourished children. Given that there are more undernourished children in India than in all of Africa, aggregating the Indian data into a single observation reduces the variation in the dataset and makes the cross-sectional dimension of the dataset much less representative of the global population of undernourished children. With Indian states included, India accounts for 22.7% of the total number of observations (Table 2), whereas treating all of India as one country unit means that it only account for 1.5% of the total sample. [9] Second, while many countries are certainly heterogeneous,

Table 1. *Description of key variables used in the study*

| Variable name | Definition | Source |
|---|---|---|
| Stunting | Percentage of children aged 0–5 who are two standard deviations less than international height for age norms | DHS (2010) |
| Underweight | Percentage of children aged 0–5 who are two standard deviations less than international weight for age norms | DHS (2010) |
| Low BMI | Proportion of adult women who with body mass index (weight for height squared) of less than 18.5 | DHS (2010) |
| Growth | Percentage change in GDP per capita, measured in local currency units | WDI (2010) |
| Growth (ag.)<br>Growth (nonag.) | The weighted percentage change in (non)agricultural GDP per capita. Two weights are used: (non)agricultural GDP shares and (non)agricultural employment shares. If the GDP shares are used then (non)agricultural GDP is divided by the total population. If employment shares are used then GDP is divided by the (non)agricultural population | WDI (2010) for national accounts data, FAO (2010) for employment data. Indian data are from national sources. |
| Growth (food prod.) | Percentage change in food production per capita, measured in 2002 international purchasing power units | FAO (2010) |
| Daily energy supply (DES) | Mean availability of calories (kcal/day) | FAO (2010) |
| Cereals + roots as % of DES | The shares of DES accounted for by cereals and root crops (a crude measure of dietary diversity) | FAO (2010) |
| Protein consumption | Mean availability of proteins (grams/day) | FAO (2010) |
| Fat consumption | Mean availability of fats (grams/day) | FAO (2010) |
| Asset-based poverty | The percentage of household who do not own of the assets or consumer durables measured in the survey | DHS (2010) |
| Female education | The proportion of adult women having attended secondary or tertiary educational institutions | DHS (2010) |
| Fertility rate (general) | Births divided by number of women 15–44 multiplied by 1000) for the 3 years preceding the survey | DHS (2010) |
| % children vaccinated | Percentage of children 12–23 months who had received nine specified vaccines | DHS (2010) |
| % births in medical facility | Percentage of live births in the last five) years preceding the survey attended by a skilled medical staff | DHS (2010) |
| % HHs with electricity | Percentage of households with access to electricity | DHS (2010) |
| % HHs with flush toilet | Percentage of households with access to a flush toilet | DHS (2010) |
| % HHs with piped water | Percentage of households with access to piped water | DHS (2010) |

Table 2. *Regional composition of the aggregate sample*

| | Number of observations of stunting | Percentage of total sample (%) |
|---|---|---|
| All observations with Indian states | 198 | 100.0 |
| Indian states | 45 | 22.7 |
| South Asia with Indian states pooled together | 16 | 10.5 |
| East Asia | 9 | 4.5 |
| Latin America & Caribbean | 34 | 17.2 |
| Middle East & North Africa | 18 | 9.1 |
| Sub-Saharan Africa | 63 | 31.8 |
| Transition countries (former Soviet Bloc) | 12 | 6.1 |

*Source:* Author's construction.

India is arguably heterogeneous in the extreme. In terms of childhood stunting in 2005, just one in five children were stunted in Kerala, yet one in two children were stunted in Bihar. Bundling very different states together is tantamount to discarding important information unnecessarily. Third, obtaining sub-national (non)agricultural GDP data for India is relatively easy, but far more difficult for most other developing countries. So in the present analysis we treat Indian states as national units, which does not seem unreasonable given that most number among the most populous units in our dataset. We also note that lack of data precludes China from our data.

Finally, it is worth noting the temporal dimensions of our data set. Table 2 notes the total number of episodes in our sample as well as the regional break-up. Appendix Table B2 also lists all the episodes in question. The number of episodes per country varies from a minimum of one to a maximum of five, but most countries have two to three episodes. Moreover, the typical length of an episode is about 4–5 years.

### (c) *Estimation strategy*

As noted in the introduction, much of the existing cross-country work on nutrition focuses solely on cross-country variation rather on explaining nutritional changes within countries. In other words the focus is on explaining the emergence of nutritional differences across countries that have emerged over the long run. By focusing on explaining changes within countries—typically over 4–5 year periods—our focus is very much on nutritional change in the medium run, which is certainly consistent with the goals and aspirations of national policymakers and their development partners. A second potential concern with cross-sectional approaches is endogeneity biases. While papers such as Smith and Haddad (2002) aim to control for simultaneity biases using country fixed effects, if these fixed effects are correlated with the error term then the estimates are biased. A special case of this bias is that, in the long run, especially, nutrition changes could affect GDP per capita, rather than vice versa (as the work of Robert Fogel (1994) others suggests).

The more recent cross-country regressions literature has therefore tended to move away from cross-sectional analyses to more dynamic regressions. In the very analogous growth-poverty literature the focus is also on explaining differences within countries, measures as either percentage changes or first differences (sometimes called poverty episodes). This differencing purges the estimation of fixed effects, although the regressions could still be biased by omitted variables that are correlated with economic growth but which also affect nutrition outcomes (Christiaensen, Demery, & Kühl, 2011; Deaton, 2006). In some instances these omitted variables could be outcomes of growth (e.g., if growth funds health or nutrition programs), but in other instances there may be a genuine simultaneity bias (e.g., if good governance causes both growth and better nutrition programs, or HIV/AIDS causes lower growth and increases malnutrition). To overcome this problem, we add fixed effects to the differenced regressions to control for unobserved country-specific trend factors that influence changes in malnutrition. To avoid confusion, this second type of fixed effect model is termed herein a "country trend effect" model (specifically, it is the linear trend among all the observations for a particular country, typically two to three). Hence, the core specification takes the form:

$$\Delta(N_{it}) = \varepsilon_Y \Delta \ln(Y_{it}) + \gamma_N N_{it-1} + c_i + u_{it} \tag{1}$$

where $N$ is the malnutrition indicator, $Y$ is the income indicator, $c$ is a country trend effect and $u$ is the error term. Note also that $N_{it-1}$ appears on the right hand side. This is the initial level of poverty/malnutrition in the episode, which represents a convergence/divergence term. [10]

A key advantage of adding the country-specific trend effect is that it forces identification of the coefficients from the within country variation, strengthening any results because of the much lower signal-to-noise ratio (Christiaensen *et al.*, 2011). However, in instances when the sample size is small it is also possible that the fixed effects drown out any true signals from the data. Hence, as a robustness test, the results of regressions that drop country trends effects are reported in the bottom row of each table. Note, also, that we typically estimate (1) in first differences rather than percentage differences, for reasons outlined in Appendix A.

After estimating Eqn. (1), we then turn to disaggregating total economic growth into its sectoral components based on an approach from the poverty-growth literature (Christiaensen *et al.*, 2011). In this approach, total GDP per total capital is disaggregated into agricultural GDP per total capita (subscript $a$) and non-agricultural GDP per total capita (subscript $n$). However, the impact of each sector's growth rate on malnutrition will obviously depend on the size of the sector, or what Christiaensen *et al.* (2011) term the "participation effect." Hence, each sector's growth rate needs to be weighted by its initial GDP share, $s$:

$$\Delta(N_{it}) = \varepsilon_a s_{a,it-1} \Delta \ln(Y_{a,it}) + \varepsilon_n S_{n,it-1} \Delta \ln(Y_{n,it}) + \gamma_N N_{it-1} + C_i + u_{it} \tag{2}$$

In Eqn. (2) the estimated effect of a sectoral growth rate is therefore conditional upon participation in the sector, $s$. For example, a given agricultural growth rate will have a large effect in an agrarian economy like Ethiopia, but no effect in a non-agricultural economy like Singapore. In addition to the approach of using sectoral GDP shares to capture participation effects, one can also use sectoral employment shares as weights and as the denominator in the per capita GDP measures. [11]

There are several other problems that invariably plague cross-country regressions (Durlauf *et al.*, 2005). First, while we have discussed simultaneity biases, there is also a large literature testing whether nutrition improves economic growth, following the efficiency wage hypothesis. While reverse causality is obviously a problem with cross-sectional "long run" regressions, it is less likely that improvements in preschooler nutrition substantially affect economic growth over the much shorter nutrition episodes used here (e.g., 5 years). The country trend effects may also control for some potential sources of simultaneity bias. [12]

## 3. PRODUCTIVE SECTOR DIMENSIONS OF NUTRITIONAL CHANGE

Regression 1 in Table 3 follows Heltberg (2009) in estimating the effect of aggregate GDP per capita growth on stunting prevalence, with the main differences being a larger sample size, the inclusion of country trend effects, and the specification of the dependent variable as a first difference rather than a percentage difference. Bearing that in mind, the results are qualitatively similar to Heltberg's. Aggregate growth significantly reduces stunting prevalence, and the effect is reasonably large. The results suggest that it would typically take a per capita growth rate of 5.5% per year to reduce stunting prevalence by around 1 percentage point per year. Such a growth rate is a rapid one, but certainly not uncommon in the past decade or so.

In Regressions 2 and 3, aggregate growth is split up into its sectoral components, with Regression 2 adopting sectoral GDP shares as weights (recall Eqn. (2)) and Regression 3 adopting sectoral employment shares as weights. In both regressions, the coefficient on agricultural growth is negative but insignificant, whereas the coefficient on non-agricultural growth is both negative and significant at the 5% level. However, Wald tests reported at the bottom of Table 3 suggest that the difference between agricultural and non-agricultural growth effects is not statistically significant since the standard errors on the agricultural growth coefficient are quite large. This might also suggest that the relationship between agricultural growth and malnutrition is quite heterogeneous, or that measurement error is a significant problem. [13]

Unfortunately, we found few means of substantially improving the precision of these estimates. Land or overall income inequality is sometimes hypothesized to condition the extent to which economic growth is pro-poor, but land inequality is very infrequently measured, and not measured in the same years as the nutrition surveys. We also tested for parameter heterogeneity by interacting growth effects with regional dummies, but none of these interactions were significant at conventional levels, although a coefficient for an interaction between agricultural growth and a dummy for Indian states was only marginally insignificant. Moreover, the introduction of this interaction term rendered the agricultural growth coefficient significant and increased its magnitude. This could perhaps suggest that agricultural growth typically does reduce stunting prevalence, but has not done so in India. Certainly some of the state level data for India are suggestive of that. Several Indian states are characterized by high economic growth rates (including in agriculture) and no reduction in stunting rates (e.g., Gujarat, Rajasthan, and Bihar). Some recent research explores this apparent agriculture-nutrition disconnect in India in more depth (Headey *et al.*, 2012).

Another means of exploring the role of agriculture is to test whether it is increased food production—rather than total agricultural production—that is the main linkage between agricultural growth and nutrition. Food production per capita is an indirect indicator of both food availability (since most poor countries are still largely dependent on domestic production rather than imports) and of agricultural productivity and income growth for the rural poor (since the poor are often

Table 3. *The impacts of economic growth on child malnutrition*

| Regression no. | 1 | 2 | 3 |
|---|---|---|---|
| Country trend effects? | Yes | Yes | Yes |
| Sector growth rate weights | Not applicable | GDP shares | Pop. Shares |
| No. of countries/states | 89 | 89 | 78 |
| No. observations | 160 | 160 | 140 |
| Initial malnutrition, $t-1$ | −0.11*** | −0.11*** | −0.11*** |
| Growth (GDP per capita) | −0.18** | | |
| Growth (ag.) | | −0.35 | −0.20 |
| Growth (nonag.) | | −0.16** | −0.26** |
| $R$-squared | 0.73 | 0.73 | 0.75 |
| Adjusted $R$-squared | 0.37 | 0.37 | 0.41 |
| Wald test indicates difference between agricultural & non-agricultural growth? | Not applicable | No | No |
| Significant changes when country trend effects are excluded? | No | No | No |

*Source:* Author's estimates. See text for details.
*Notes:* These are fixed effects regressions with dependent variables in first differences and independent variables in percentage differences.
* Indicates significance at the 10% level.
** Indicates significance at the 5% level.
*** Indicates significance at the 1% level.

Table 4. *The conditional impacts of changes in food production per capita on childhood malnutrition*

| Regression no. | 1 | 2 |
|---|---|---|
| Dep. variable | Δ Stunting (% points) | Δ Stunting (% points) |
| Country trend effects? | Yes | Yes |
| Sector growth rate weights | Not applic. | Not applic. |
| No. of countries/states | 67 | 67 |
| No. observations | 124 | 124 |
| Initial malnutrition | −0.11*** | −0.11*** |
| Initial food production, log | −2.21 | −2.73# |
| Growth of food production: | −0.07 | |
| If initial food production <$75 | | −0.35** |
| If $75 <initial food production <$150 | | −0.31** |
| If initial food production >$150 | | −0.05 |
| $R$-squared | 0.72 | 0.74 |
| Adjusted $R$-squared | 0.35 | 0.39 |
| Significant changes when country trend effects excluded? | No | No |

*Source:* Authors' estimates. See text for details.
*Notes:* These regressions are with dependent variables in first differences and independent variables in percentage differences.
* Indicates significance at the 10% level.
** Indicates significance at the 5% level.
*** Indicates significance at the 1% level.
\# Indicates marginal insignificance at the 10% level.

food producers). However, the effects of food production growth are likely to be heterogeneous across countries. In somewhat more advanced developing countries it is possible that increased food production has little or no impact on nutrition because food availability is less of a constraint than other factors (poor access to health services, or residual inequalities), because fewer poor or malnourished people work in the agricultural sector, or because economic diversification encourages greater reliance on food importants.

For these reasons Table 4 reports both a linear model (regression 1) and a model where we split up the sample according to different levels of initial food production per capita. Regression 1 for the whole sample shows that growth in food production has no significant effect on stunting. However, when we split up the sample into low, medium, and high levels of initial food production per capita we find that growth in food production per capita has a significant and negative effect in all but the high food production category (initial food production per capita greater than $150). The coefficients for the low and middle categories are not significantly different to each other, and the point estimates are reasonably close in magnitude and quite large. These point estimates suggest that if food production per capita were to grow at 3% per annum, then stunting should reduce by 1% per annum.[14]

In summary, we have found that overall economic growth is a robust and strong predictor of reductions in stunting, and that growth in food production has quite large marginal effects in countries with lower levels of initial food production. Hence there does appear to be some basis for believing that increased productivity of the food sector plays a special role, although there is no evidence that agriculture as a whole is particularly important.

## 4. SOCIAL AND INFRASTRUCTURAL DIMENSIONS OF NUTRITIONAL CHANGE

Economic growth and monetary poverty indicators have well known flaws as indicators of general economic development, and in the context of explaining malnutrition some of these flaws could be serious. Nutrition outcomes are widely established as being strongly influenced by health and female education outcomes, for example, but these outcomes are sometimes only weakly correlated with monetary indicators of development. In this section we therefore explore some potential social and infrastructural determinants of nutrition outcomes. Specifically we test eight indicators drawn from the Demographic Health Surveys (DHS, 2010), all of which have been used as explanatory variables in survey-based studies of malnutrition: [15]

1. Percentage of households that own at least one of a country-specific list of assets (i.e., the converse of an asset-based ultra-poverty measure), hereafter termed "changes in asset ownership";
2. Percentage of households with access to piped water;
3. Percentage of households with access to flush toilets;
4. Percentage of households with access to electricity;
5. Percentage of children aged 12–23 months having received all of a set of nine vaccinations;
6. Percentage of births attended by skilled medical staff;
7. Percentage of adult women having completed secondary or tertiary education;
8. Average fertility rate.

The list of variables could potentially be longer, but the set above was determined by our interest in policy-related variables and by data limitations. [16] That most of the variables listed above could influence stunting outcomes is fairly obvious (see Section 2 for some discussion), although in some cases the linkages are fairly indirect (e.g., electricity).

To explore how robustly changes in these eight variables ($y$-axess) predict changes in stunting ($x$-axis) across countries, Figure 1 presents scatter plots for each of the eight explanatory variables. Note that each scatter has a regression line, which iteratively places less weight on outlying observations. The results suggest that the strongest relationships hold for ownership of at least one asset, medically attended births, women's secondary/tertiary education, and fertility rates. The percentage of young children vaccinated also has a negative slope coefficient, but the relationship is somewhat weak. [17] Interestingly, the three infrastructure variables—piped water, flush toilets, and electricity—all show very weak relationships, suggesting their relationship to nutrition is not very robust. Although we suspect that these weak relationships partly stem from the fact that these factors really are less important drivers of nutritional change, it could well be that piped water and flush toilets are very poor proxies for water and sanitation quality (Klasen, Tobias, Kristina, & Johannes, 2012; Smith & Haddad, 2002).

Table 5 shows two regressions which confirm this pattern of bivariate results in a multivariate context (because of sample size constraints, the country trend effects in these regressions are dropped). The first equation shows the coefficients and associated $p$-values in a general regression model containing all of the candidate variables. By iteratively dropping the least significant variables (i.e., the general to specific method), and then dropping piped water—which is significant but has an unexpected sign—one arrives at a specific model containing two highly significant variables (changes in fertility and changes in asset-based poverty) and two marginally insignificant variables (medical births and female education).

Hence, at the national level there is indeed some evidence that "social sector" factors matter, such as the extent of (asset-based) poverty reduction, fertility rates and—less robustly—female secondary education, and access to medical services. As we noted above, these variables should perhaps be considered imperfect proxies for more general social services and poverty reduction factors. For example, mothers who have births that are medically attended will also be more likely to have received antenatal care, [18] and their children are more likely to be vaccinated. Likewise, women's education

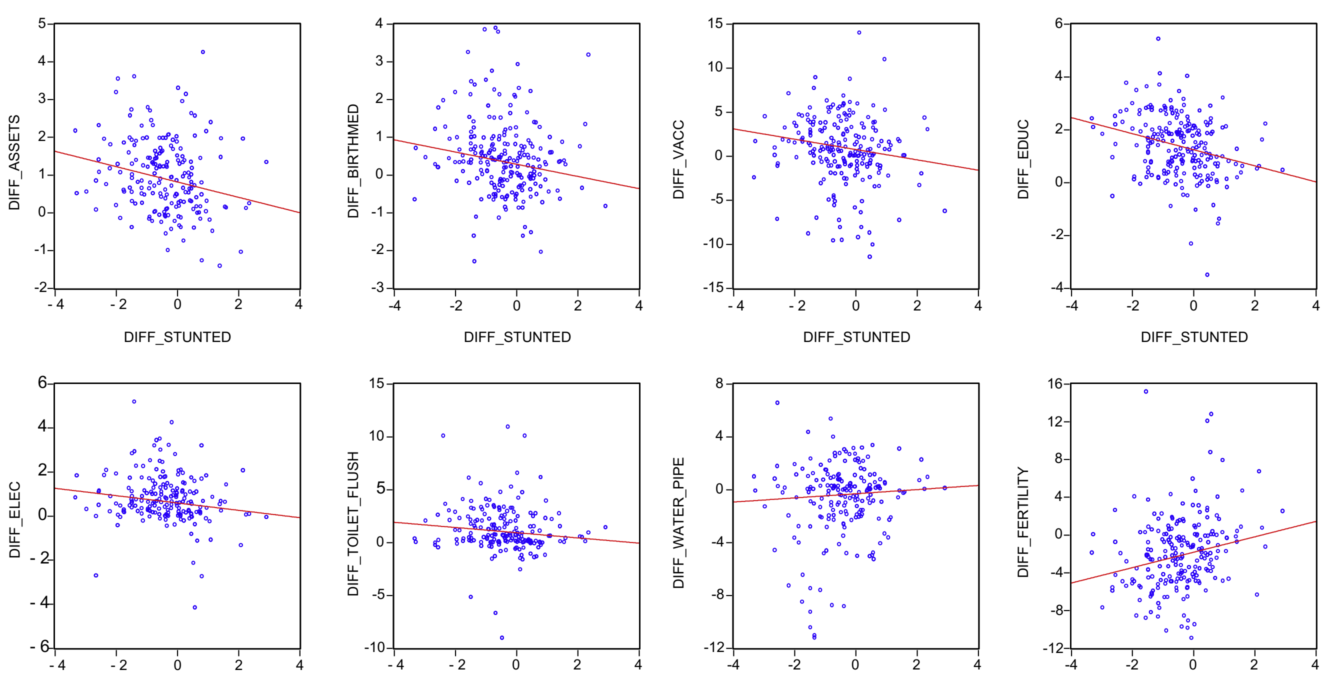


Figure 1. *Scatter plots of changes in stunting against changes in nutrition-relevant socioeconomic indicators. Source: Author's estimates. Notes: Regressions are performed with 10 robustness iterations to minimize the influence of outliers. This technique runs a regression, calculates residuals, and then uses the inverse of the absolute residuals as weights in the subsequent regression, etc. See Table 1 for definitions of the variables.*

Table 5. *Testing socioeconomic predictors of nutritional change*

| Regression no. | 1 | | 2 | |
|---|---|---|---|---|
| Dep. variable | ΔStunting (% points) | | ΔStunting (% points) | |
| Country trend effects? | No | | No | |
| Outliers removed | Yes | | Yes | |
| Sector growth rate weights | Not applic. | | Not applic. | |
| No. of countries/states | 113 | | 115 | |
| No. observations | 173 | | 177 | |
| | Coefficient | *p*-Value | Coefficient | *p*-Value |
| Change in asset ownership | −0.27*** | 0.01 | −0.25*** | 0.002 |
| Change in medical births | −0.12 | 0.17 | −0.12 | 0.17 |
| Change in female education | −0.13 | 0.13 | −0.12 | 0.14 |
| Change in fertility | 0.19** | 0.04 | 0.20*** | 0.01 |
| Change in vaccinations | 0.002 | 0.90 | | |
| Change in electricity | 0.02 | 0.82 | | |
| Change in flush toilets | 0.001 | 0.98 | | |
| Change in piped water | 0.05 | 0.07 | | |
| $R$-squared | 0.16 | | 0.15 | |
| Adjusted $R$-squared | 0.12 | | 0.13 | |

*Source:* Authors' estimates. See text for details.
*Notes:* These regressions are with dependent and independent variables in first differences.
* Indicates significance at the 10% level.
** Indicates significance at the 5% level.
*** Indicates significance at the 1% level.

may partly represent gender attitudes and female empowerment (Haddad, 1999). And as we noted above, fertility rates represent a number of family planning factors.

Another issue of interpretation is how these factors interact. Certainly one explanation for the insignificance of the coefficient attached to female secondary education in Table 5 is that female education is strongly correlated with fertility rates (Schultz, 1997). In Table 6 we therefore explore some of the relationships between these social sector outcomes, and their relationship to economic growth. The results suggest that economic growth has a positive effect on all four outcomes. For example, the point estimates suggest that a doubling of GDP per capita would increase women's secondary education by 14 percentage points, and access to medical births by 18 percentage points. The direct effect of economic growth on fertility rates is weaker (Regression 3), but fertility rates are also driven by changes in female education. Hence, Regression 3 also includes changes in female education as an explanatory variable for changes in fertility. The coefficient on female education is large and highly significant in this regression, suggesting that when economic growth is allowed to influence fertility rates via changes in female education, the predicted impact of a doubling of GDP per capita is again about 16 percentage points (i.e., from the direct effect and the indirect effect of increasing female education). Somewhat surprisingly, it is only asset ownership that is quite unresponsive to economic

Table 6. *Estimating the impact of economic growth on changes in socioeconomic indicators*

| Regression no. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Dep. variable | Change in female education | Change in medical births | Change in fertility rates | Change in asset ownership |
| Country trend effects? | No | No | No | No |
| Outliers removed | Yes | Yes | Yes | Yes |
| Sector growth rate weights | Not applic. | Not applic. | Not applic. | Not applic. |
| No. of cross-sections | 55 | 55 | 55 | 55 |
| No. of observations | 85 | 85 | 85 | 85 |
| Economic growth | 0.14*** | 0.18*** | 0.10** | 0.08* |
| Initial level of dependent var. | 0.02** | −0.01* | 0.001 | 0.19*** |
| Change in female education | | | −0.35*** | |
| $R$-squared | 0.24 | 0.15 | 0.29 | 0.31 |
| Adjusted $R$-squared | 0.22 | 0.13 | 0.02 | 0.30 |
| Estimated change in dependent variable from a doubling of GDP per capita | 14 points | 18 points | 16 points | 8 points |
| Qualitative changes on growth coefficient when country trend effects included? | No | No | No | Yes, larger & more significant |

*Source:* Authors' estimates. See text for details.
*Notes:* These regressions are with dependent variables in first differences and independent variables in percentage differences.
Because of the small sample size, country trend effects were not included, although their inclusion did not materially alter results.
* Indicates significance at the 10% level.
** Indicates significance at the 5% level.
*** Indicates significance at the 1% level.

growth, although this could be related to the specific asset indicator used. First, being a measure of assets, it says nothing about food affordability, which is arguably the dimension of household poverty that is most relevant to malnutrition. Second, since ownership pertains to any listed asset, the measure is really an indicator of welfare improvement for the very poorest. Economic growth probably has much larger effects on less stringent measures of asset ownership. That said, other research also finds weak linakges between economic growth rates and asset ownership (Harttgen, Klasen, & Vollmer, 2012).[19]

Finally, we note that although the marginal effects of economic growth on these four variables are reasonably strong, the coefficient of determination is generally around 0.30, suggesting that plenty of other omitted factors (and measurement error) account for the residual variation. So while economic growth does typically have an effect on pro-nutrition development factors, the relationship is not so strong as to rule out significant country level idiosyncrasies.

## 5. INSIGHTS FROM NUTRITION SUCCESS STORIES

Among their flaws, cross-country regressions have a limited capacity to shed light on the variety of experiences within any given relationship. To garner a different kind of insight into the determinants of changes in malnutrition, this section looks at successful nutritional episodes at the national level,[20] much in the vein of the general economic growth literature on this topic (Hausman, Rodriguez, & Wagner 2006; Hausman *et al.* 2005). The specific goal of this exercise is to see whether these successes are consistent with the findings in previous sections on the general role of economic growth, the conditional role of growth in food production, and the important role of nutrition-sensitive social development. A more indirect goal is to pose additional questions for future research, since the literature on nutrition success stories (and failures) is rather sparse.

As for the basic criteria for success, these are twofold. First, a country (or Indian state) must show progress against at least one childhood malnutrition indicator (stunting or underweight prevalence) that is faster than 1 percentage point per year. While this is somewhat arbitrary, it so happens that this is the minimum speed of progress for ensuring success in meeting the MDG target of halving malnutrition in 25 years (1990–2015), unless initial malnutrition prevalence was well above 50% (which was rare by 1990). Second, there must at least be some progress against the other childhood malnutrition indicator (in other words, a country/state cannot show progress against stunting and regression against underweight prevalence, or vice versa). However, in some cases only one indicator is available.[21] Finally, episodes that are consistent with these criteria are further grouped into three categories: episodes characterized by a well documented nutrition program thought to be relatively successful; episodes that cover Asia's Green Revolution period; and a residual category of

Table 7. *Historical episodes of rapid reductions in childhood malnutrition*

| Episodes | Change in underweight (points/p.a.) | Change in stunting (points/p.a.) | Better diets? (calories, proteins, fats) | Growth > 5% p.a.? (agric. > 3%/p.a.) | Favorable health, education, and fertility trends? |
|---|---|---|---|---|---|
| *Successes with well-documented nutrition programs* | | | | | |
| Bangladesh 1994–05 | −2.0 | −2.0 | Very rapid | Yes (agric) | Yes |
| Brazil 1986–96 | −0.7 | −1.9 | Yes | No | Yes (very rapid) |
| Honduras 1996–01 | −1.3 | −1.8 | Diversifying | No | Yes |
| Mexico 1989–99 | −1.2 | −1.9 | No | No | Yes |
| Senegal 2000–05 | −1.2 | −1.9 | Modest | Yes | Modest |
| Tamil Nadu 1992–98 | −1.9 | N.A. | Diversifying | Yes | Yes |
| Thailand 1982–90 | −2.9 | N.A. | Very rapid | Yes | Yes |
| Vietnam 1994–06 | −1.5 | −1.3 | Very rapid | Yes (agric) | Yes |
| *Green Revolution episodes with marked growth in cereal production* | | | | | |
| Bangladesh 1985–94 | −1.1 | N.A. | Very rapid | Yes (GDP = 4.7%) | Yes |
| China 1992–02 | −1.1 | N.A. | Yes | Yes (agric) | Yes (exc. fertility) |
| India 1977–92 | −1.3 | N.A. | Very rapid | Yes (agric) | No (exc. fertility) |
| Philippines 1973–82 | −1.9 | N.A. | Yes (cereals) | Yes (agric) | Yes (education) |
| Sri Lanka 1977–87 | −1.8 | −1.3 | Yes (protein) | Yes (agric) | Yes |
| Thailand 1982–90 | −2.9 | N.A. | Very rapid | Yes | Yes |
| Vietnam 1994–06 | −1.5 | −1.3 | Very rapid | Yes (agric) | Yes |
| "*Unproven*" *recent successes* | | | | | |
| Angola 1996–01 | −1.9 | −2.2 | Yes | Yes (agric) | Yes (exc. fertility) |
| Cambodia 1996–06 | −1.4 | −1.5 | Yes | Yes (agric) | Yes |
| Ethiopia 2000–05 | −1.5 | −1.3 | Yes | Yes (agric) | Only fertility |
| Ghana 2003–06 | −1.6 | −2.5 | Yes | Yes (agric) | Only education |
| Indonesia 2001–04 | −1.2 | −4.3 | Diversifying | Yes (agric) | Yes (exc. fertility) |
| Kyrgyzstan 1997–06 | −0.6 | −1.6 | Modest | No | Yes (exc. fertility) |
| Mongolia 1999–04 | −1.2 | −1.3 | No (decline) | Yes | Yes |
| Orissa 1998–05 | −1.3 | −0.6 | No (decline) | Yes | Yes (exc. fertility) |
| Rajasthan 1998–05 | −0.6 | −1.8 | No (decline) | No | Yes |
| Tanzania 1996–05 | −1.5 | −0.6 | Diversifying | Yes (agric) | No |
| Uzbekistan 1996–06 | −1.1 | −1.9 | No | Yes (agric) | Yes (exc. fertility) |
| Zambia 2002–07 | −1.8 | −1.5 | No | Yes (agric) | No |

*Source:* Author's construction.
*Notes:* See text for details of all variables.

unproven and relatively recent episodes where it is not yet clear if the nutritional improvements will be sustained. Results are presented in Table 7.

We leave readers to peruse Table 7 in detail. Here we emphasize that the results in Table 7 suggest some important "stylized facts" that largely complement the formal econometric analyses of previous sections. First, improvements in malnutrition are often, but not always, accompanied by socioeconomic improvements on several fronts. Looking at the first category of episodes, Brazil, Mexico, and Honduras are three middle income countries that achieved significant nutritional progress without rapid economic growth. However, in the poorer countries in Table 7 it appears that economic growth always accompanies sustained nutritional improvements.

Second, evidence on positive dietary change is less clear (because of poor quality and highly aggregated data), but also appears consistent with the result in Section 3 that growth in food production is at least important at lower levels of initial production. However, in the third category of more recent but "unproven" success stories, we often find little evidence that diets are improving at an aggregate level. If a steady improvement in diets is indeed a prerequisite for longer term nutritional improvements, then these "unproven" success stories may not be sustainable.

Third, the more established success stories all show social and economic improvements in terms of better access to education and health services, and lower fertility rates. India is a partial exception in that the Green Revolution episodes saw very little improvement in national education and health outcomes, although fertility rates did decline quite substantially (indeed, Jensen 2012 estimates that fertility reductions accounted for perhaps one-third of India's nutritional improvements over this period). So broader social and economic progress seems to be a key component of sustained success.

Finally, Table 7 indirectly suggests that more research is needed on national level nutritional success stories, especially with regard to clarifying and quantifying the relative roles of dietary improvements (and agricultural drivers thereof), nutrition programs, social sector developments, and broader economic developments, including income growth. Our econometric results and the basic summary results in Table 7 both suggest that rapid and sustained improvements in malnutrition require a range of different investments. A very real example of this is Bangladesh. While we have included "Bangladesh 1994–2005" under the category of "Successes with well-documented nutrition programs", in fact the Bangladesh Integrated Nutrition Program (BINP) has received mixed evaluations (World Bank. 2005). Moreover, Bangladesh was already making fairly rapid progress against malnutrition prior to the implementation of the program.

So what are some of the likely drivers of nutritional change in Bangladesh? Table 8 documents socioeconomic progress across a broader range of indicators over the period 1997–2007. In this 10 year period the prevalence of stunted children and underweight women both fell by almost 20 percentage points. Strikingly, this progress was accompanied by rapid development on many fronts. GDP per capita and crop production per capita increased by 47% and 33% respectively, and asset-based poverty fell by 11.6 percentage points, or 20%. On physical infrastructure, access to improved water improved little (though it was quite high already), but access to improved sanitation and electricity increased rapidly, especially the latter. On health there was very rapid progress on all fronts, except the nutrition-specific variable of exclusive breastfeeding. And on other social indicators there was a doubling of the percentage of women with some secondary education, and rapid reductions in both total fertility and adolescent fertility. And although no MFI indicators are shown in Table 8, Bangladesh is also famous for a microfinance revolution, which also had important gender dimensions to it.

Hence there are a number of plausible drivers of nutritional change in Bangladesh and in the other success stories listed in Table 7. What we do not know is precisely what role each of these factors play, let alone the more elusive calculus of cost-benefit ratios for different interventions. Our results do suggest, however, that nutritionists and social scientists should pay greater attention to some of the socioeconomic drivers of nutritional change, particularly as many of relevant interventions—such as female education and family planning policies—have developmental benefits that go extend beyond improved nutrition outcomes.

## 6. CONCLUSIONS

In contrast to much of the specialized nutrition literature, this paper explores the extent to which "non-nutrition" factors play a role in reducing chronic childhood malnutrition (stunting). Unlike most previous research we have focused on the role of such factors in the short to medium term, consistent with the ambitions of the MDGs and other development initiatives.

Table 8. *Trends in nutrition outcomes and "nutrition−sensitive" variables in Bangladesh: 1997–2007*

| Indicators | 1997 | 2007 | Change (%) | Indicators | 1997 | 2007 | Change (%) |
|---|---|---|---|---|---|---|---|
| *Nutrition outcomes* | | | | *Social: health* | | | |
| Underweight (%)[c] | 56.4 | 46.1 | −18.3 | Mortality/1000 children[d] | 101.5 | 57.1 | −43.7 |
| Stunting (%)[c] | 54.7 | 36.0 | −34.2 | Physicians/1000 people [d] | 0.2 | 0.3 | 50.0 |
| Low BMI women (%)[c] | 52.0 | 32.8 | −36.9 | Prenatal care (%)[d] | 26.4 | 51.2 | 93.9 |
| Economic | | | | Medical births (%)[c] | 4.1 | 13.6 | 231.7 |
| Crop production p.c.[d] | 81.2 | 108.4 | 33.4 | Infant breastfeeding (%)[b] | 46 | 42.9 | −6.7 |
| GDP p.c. ($)[d] | 878 | 1291 | 47.0 | All vaccinations (%)[c] | 54.2 | 81.9 | 51.1 |
| Poverty, no assets (%)[c] | 58.0 | 46.4 | −20.0 | Social: other | | | |
| Infrastructure | | | | Female sec. schooling (%)[c] | 18.2 | 36.3 | 99.5 |
| Improved water (%)[d] | 78[a] | 80.0 | 2.6 | Births per woman [d] | 3.5 | 2.4 | −31.4 |
| Improved sanitation (%)[d] | 42[a] | 53.0 | 26.2 | Births per 1000 women | 130.5 | 78.9 | −39.5 |
| Electricity (%)[c] | 22.4 | 46.5 | 107.6 | Aged 15–19[d] | | | |

*Source:* World Bank. (2011) and DHS (2011). See notes below for further details.
[a] Measured in 1995 rather than 1997.
[b] Measured in 2000 rather than 1997.
[c] Sourced from DHS (2011).
[d] Sourced from World Bank (2011).

What are our key results? First, economic growth does typically lead to reductions in stunting, even over relatively short periods. On average, it takes an eminently feasible 5.5% per annum increase in per capita GDP to reduce stunting prevalence by a full percentage point. This result is broadly consistent with previous research summarized in our introduction.

Second, while we only find weak evidence that agricultural growth plays any special role, growth in food production does seem to reduce stunting, but only at relatively low levels of initial production. This result is fairly intuitive, but there is substantial scope to improve our understanding of the linkages between agricultural development and nutrition outcomes, as other recent research suggests (Fan & Pandya-Lorch, 2012).

Third, the only socio-economic factors that significantly account for nutrition changes across countries are improvements in female secondary education, reductions in fertility (which is, in turn, closely associated with changes in female education), asset accumulation (which is surprisingly weakly explained by economic growth), and increased access to health services. Infrastructural variables—such as improved water, sanitation, and electricity—did not appear to explain nutritional change over time.

We also note that many of these results—though not all—extend to two alternative indicators of malnutrition, although neither childhood underweight prevalence nor adult BMI can really be regarded as good indicators of chronic malnutrition, since they partly capture recent deprivations in food intake or health outcomes. [22]

We believe that some of these findings have important implications for future research. We find enough evidence to suggest that growth in food production could well be important for reducing malnutrition in the poorest countries. This would tend to justify the increased interest in agricultural interventions for nutrition (Fan & Pandya-Lorch, 2012; Hoddinott *et al*., 2012), although we really know relatively little about this relationship. The linkages between the two sectors are complex, and possibly highly context specific. Hence a great deal more research is needed on how different agricultural strategies and conditions really influence malnutrition.

Second, it is perhaps surprising that more economic research has not focused on some of the other socioeconomic drivers of nutritional change identified above. Of these, female education has perhaps received the most attention in nutritional research (for example, Webb & Block, 2004) and in the broader development literature (King, Klasen, & Porter, 2008). However, the role of family planning in nutritional change remains a much more neglected area of research, with only bits and pieces of research in the economic (Jensen 2012) and nutritional literatures (Dewey & Cohen 2007). Moreover, a recent Copenhagen Consensus paper on population policies estimated relatively high benefit-cost ratios, without even considering nutritional improvements as one of the benefits (Kohler, 2012). Hence it is certainly conceivable that some of these broader social investments could have high pay-offs once the nutritional and extra-nutritional benefits are accurately accounted for.

## NOTES

1. Among others, see: Behrman, Alderman, & Hoddinott, 2004; Grantham-McGregor, Fernald, & Sethurahman, 1999; Hoddinott, 2009; Horton & Ross, 2003; Maluccio *et al*., 2009; Strauss & Thomas, 1998; World Bank, 2006; Deaton, 2009.

2. See http://www.copenhagenconsensus.com/Projects/Copenhagen%20Consensus%202008-1.aspx

3. This includes the UN-led Scaling Up Nutrition (SUN) initiative, USAID's Feed the Future, a DFID-World Bank program to address malnutrition in South Asia. However, OECD data suggest that foreign aid spending on nutrition is very low (about 300 million USD), or less than 1% of total foreign aid. See http://blogs.worldbank.org/meetings/node/612

4. Smith and Haddad review many other studies that look at relationships between nutrition and income, and there have been several studies since in addition to those discussed above, such as Apodaca (2008) and Gabriele and Schettino (2008). However, all of these studies look at cross-sectional "long run" relationships. Two papers that are more dynamic are Heltberg's (2009) cross-country analysis and Cole (2003).

5. While they chiefly rely on cross-sectional regressions, Webb and Block (2010) do note that "Although these general tendencies observed across countries and across years are robust, the particular experience of any individual country over time will vary idiosyncratically."

6. The cited study by Haddad *et al*. (2003) looks at income/expenditure association with malnutrition in nine countries and finds quite robust negative gradients. In an earlier version of this paper we looked at national wealth index-malnutrition gradients across 60 or so developing countries included in the DHS. The relationship between wealth quintiles and stunting was negative in every country except the most recent survey in Egypt. See Headey (2011).

7. There are other variables that sometimes feature in nutrition studies, such as gender inequality measures, but these indicators change slowly over time and have limited availability.

8. One concern with using height as a measure of malnutrition is that it may be partially determined genetically. But while some authors still argue that genetics matter (Nubé, 2007), the WHO Multi-Center Growth Reference Study has shown, through work in multiple countries, that ethnicity and genetics matter less than environmental circumstances related to child growth (see http://www.who.int/childgrowth/mgrs/en/). Moreover, long-run historical data (Cole, 2003; Deaton, 2008) verify that heights do increase with improvements in incomes, education, and healthcare, among other factors. Hence, at the very least, changes in stunting prevalence seems a good indicator of nutrition improvements.

9. Of course, this solution is only piecemeal—East Asia is still heavily under-represented in the sample—but the difficulties of finding subnational economic growth statistics for other countries make any further expansion of the dataset very challenging indeed.

10. Note that in the poverty regression we use both the initial Gini coefficient and the initial poverty rate in the episode, whereas the Gini coefficient is not available for the malnutrition regressions.

11. In principle, this is a preferred approach, but in practice measurement error may be more of an issue with the employment estimates since labor force censuses are quite rare in developing countries, and because the nonfarm diversification of "agricultural" households can lead to overestimation of the size of agricultural employment (Headey, Bezemer, & Hazell, 2010).

12. Comments on earlier drafts of this paper suggested exploring instrumentation strategies, but these strategies are either not possible or unlikely to be valid. In cross-country settings it is virtually impossible to

find theoretically plausible instruments (in this case a factor that causes economic growth but not nutrition), and time series panel techniques that rely on lag structures as instruments (e.g., dynamic GMM) are not feasible because of the unbalanced time series structure of the panel (i.e. nutrition episodes vary in length). These panel techniques also suffer from limitations when the time dimension of the panel is small relative to the cross-section (Roodman, 2004), which is true of the datasets in this study. For these reasons – and because the dynamic nature of the estimator makes simultaneity biases unlikely – we chose not to experiment with instrumentation strategies.

13. There could be a number of issues. Agricultural employment is very difficult to measure because rural people diversify their incomes. Agricultural growth can also be much more volatile than nonagricultural growth because of rainfall dependence.

14. Note that we attempted different types of interaction terms, such as interacting growth in food production per capita with initial food production per capita, but these interactions did not produce sufficiently precise estimates.

15. See the DHS website for any number of papers that estimate the determinants of malnutrition using these kinds of variables: http://www.measuredhs.com/pubs/

16. Other variables of interest include cultural or institutional variables, such as feeding practices or gender attitudes. However, their relation to specific interventions is much more indirect, and they would typically not change much in the short episodes considered here. Yet, while it needs to be acknowledged that other variables may warrant future attention, the list above is still quite representative in that it includes indicators of material poverty, infrastructure, sanitation, health access, education, and fertility.

17. One problem here is that vaccinations are really only relevant for children aged 1 year and above, but we are unable to disaggregate our national statistics by age.

18. In the Indian DHS for 2005, for example, the correlation between antenatal care and medically attended births is 0.34, which is highly significant, while the correlation with having received any vaccination is 0.16, which is also significant.

19. Of course, a caveat here is that reverse causality is more likely a problem in these regressions than in the stunting regressions, since a factor like education might influence economic growth in the short run. The bias is not very large, but this caveat is worth bearing in mind.

20. Note that in the working paper version of this paper we also look at national level nutrition failures. We found that many of these were explained by conflict, although there were some unexplained failures, particularly Egypt, Kazakhstan, and several Indian states, all of which experienced significant economic growth and at least some progress on socioeconomic fronts. Also note that women's BMI is not examined here because there are insufficient data and the episodes in question are generally very short.

21. While the focus on both stunting and underweight prevalence is somewhat inconsistent with the econometric analyses above, the incorporation of underweight prevalence is necessary for expanding the sample size.

22. Appendix B reports some results of using these alternative indicators. For example, economic growth significantly explains reductions in female BMI. For underweight prevalence only agricultural growth or growth in food production per capita are significant. In terms of socio-economic factors, changes in asset-based poverty and female secondary education are significant determinants of changes in underweight prevalence, but medical births and fertility rates are not significant (nor are any other tested factors). Of course, neither of these alternative indicators are regarded as good indicators of chronic malnutrition since they partly capture acute malnutrition.

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## APPENDIX A. SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.worlddev.2012.07.002.