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EXPLAINING CHILD MALNUTRITION IN DEVELOPING COUNTRIES: A CROSS-COUNTRY ANALYSIS

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ABSTRACT

This paper draws on the experience of the 1970-95 period to (1) elucidate some of the main causes of child malnutrition in developing countries; (2) undertake projections of how many children are likely to be malnourished in the year 2020 given current trends; and (3) identify priority actions for reducing malnutrition the most quickly in the coming decades. The analysis is based on country fixed-effects multivariate regression using data from 63 countries. The paper finds four "underlying" determinants to be key factors: health environments, women's education, women's relative status, and per capita food availability. Two "basic" determinants are also found to be important: per capita national incomes and democracy. Due to data scarcities, the role of poverty could not be assessed. Improvements in women's education was found to have contributed the most to past reductions in child malnutrition. For Sub-Saharan Africa and South Asia—the regions with the highest child malnutrition rates—the paper identifies two priority areas for future reductions in child malnutrition: per capita food availabilities and women's education.

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1. INTRODUCTION

The causes of child malnutrition are complex, multidimensional, and interrelated. They range from factors as broad in their impact as political instability and slow economic growth to those as specific in their manifestation as respiratory infection and diarrheal disease. In turn, the implied solutions vary from widespread measures to improve countries' stability and economic performance to efforts to enhance access to sanitation and health services in individual communities. Debates continue to flourish over what the most important causes of malnutrition are and what types of interventions will be most successful in reducing it.

An understanding of the most important causes of malnutrition[1] is imperative if the current unacceptably high numbers of malnourished children are to be reduced. In 1995, 167 million children under five years old—almost one-third—were estimated to be underweight in developing countries (Table 1). The region with by far the highest prevalence, at 50 percent, is South Asia. This region is also the home of the highest numbers of malnourished children, 86 million (50 percent of the developing-country total). About one-third of Sub-Saharan African children and one-fifth of East Asian children are underweight. While the regional underweight prevalences of the Near East and North Africa and Latin America and the Caribbean are below 15 percent, pockets of severe malnutrition within the regions, particularly in some Caribbean and Central American countries, remain.

Malnutrition causes a great deal of human suffering—both physical and emotional. It is a violation of the child's human rights (Oshaug, Eide, and Eide 1994). A major waste of human energy, it is implicated in more than half of all child deaths world-wide. Adults who survive malnutrition as children are less physically and intellectually productive and suffer from higher levels of chronic illness and disability (UNICEF 1998). The personal and social costs of continuing malnutrition on its current scale are enormous.

While the number of malnourished children in the developing world has remained roughly constant, the *prevalence* of child malnutrition has been progressively declining

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[1] Malnutrition is associated with both undernutrition and overnutrition. In this paper, we use the term to refer to cases of *under*nutrition as measured by underweight rates. A child is considered underweight if the child falls below an anthropometric cutoff of -2 standard deviations below the median value of weight-for-age using National Center for Health Statistics/World Health Organization standards.

(Table 1). It fell from 46.5 percent to 31 percent between 1970 and 1995, about 15 percentage points overall. This decline indicates that, although reducing child malnutrition to minimal levels remains a huge challenge, fairly substantial progress has been made over the last 25 years. The pace of progress has varied among the regions, however. Prevalences have fallen the fastest for South Asia (23 percentage points) and the slowest for Sub-Saharan Africa (4 percentage points). In recent years there has been a deceleration: whereas from 1970-85 the developing-world prevalence fell by 0.8 percentage points per year, from 1985-95 it fell by only 0.33. The situation is particularly troubling in Sub-Saharan Africa, whose prevalence of underweight children actually *increased* from 26 percent to 31 percent between 1985 and 1995. Since 1970, underweight rates decreased for 35 developing countries, held steady in 15, and increased for 12, with most of the latter countries being in Sub-Saharan Africa (WHO 1997).

Why have some countries and regions done better than others in combating child malnutrition? The overall objective of this study is to use historical cross-country data to answer this question. The study aims to improve our understanding of the relative importance of the various determinants of child malnutrition, both for the developing countries as a whole and for each individual region. In doing so, it also aims to contribute to the unraveling of some important puzzles currently under debate: (1) Why has child malnutrition been rising in Sub-Saharan Africa? (UN ACC/SCN 1997); (2) Why are child malnutrition rates in South Asia so much higher than those of Sub-Saharan Africa, i.e., what explains the so-called “Asian Enigma”? (Ramalingaswami, Johnsson, and Rohde 1996; Osmani 1997); (3) How important of a determinant of child malnutrition is food availability at a national level? (Smith et al. 1998; Haddad, Webb, and Slack 1997); (4) How important are women’s status and education? (Quisumbing et al. 1995; Osmani 1997; Subbarao and Raney 1995); (5) How important are national political factors (such as democracy) and national incomes, and through what pathways do they affect child malnutrition? (Anand and Ravallion 1993; Pritchett and Summers 1996). By answering these questions we hope to contribute to the debate on how to make the best use of available resources to reduce child malnutrition in the developing countries at the fastest pace now and in the coming years to 2020.

The study employs the highest quality, nationally-representative data on child underweight prevalences that are currently available for the period 1970-1996 to undertake a cross-country regression analysis of the determinants of child malnutrition and to identify priorities for the future. It is different from past cross-country regression studies in four important ways. First, extreme care has been taken in assembling, cleaning and documenting the data utilized. The credibility of the child malnutrition data in terms of their quality is of obvious importance to the credibility of the conclusions drawn from their use. However, little attention has been paid to this issue outside of the World Health Organization's excellent Global Database on Child Growth and Malnutrition (WHO 1997), from which most of the data employed in this study are drawn. Second, the econometric techniques employed are more rigorous than most other studies. A number of specification tests are undertaken to establish the robustness of the results and the soundness of the specification and estimation procedures. Third, the study goes beyond the simple generation of elasticities to estimate the contribution of each nutrition determinant to reductions in child malnutrition over the past 25 years. Fourth, national food availability projections from the IFPRI IMPACT model (Rosegrant, Agcaoili-Sombilla, and Perez 1995), together with assumptions as to future values of other determinants, are used to project levels of malnutrition in the year 2020 under pessimistic, optimistic, and status quo scenarios, and key policy priorities for each developing region are laid out.

In the next section, a conceptual framework for the determinants of child malnutrition is presented. In Section 3, a review of previous cross-national studies on health and nutrition is undertaken. Sections 4 and 5 present the data, methods, and estimation results of the study. Section 6 contains a retrospective analysis of how child malnutrition has been reduced over the last 25 years; Section 7 contains projections of child malnutrition for the year 2020. In Section 8, regional policy priorities for reducing child malnutrition over the coming decades are discussed. The report concludes with a summary of its main findings and recommendations for future research.

2. CONCEPTUAL FRAMEWORK: THE DETERMINANTS OF NUTRITIONAL STATUS

The conceptual framework underlying this study (Figure 1) is adapted from the United Nations Children's Fund's framework for the Causes of Child Malnutrition (UNICEF 1990, 1998) and the subsequent Extended Model of Care as presented in Engle, Menon, and Haddad (1997). The framework is comprehensive, incorporating both biological and socioeconomic causes, and encompasses causes at both micro and macro levels. It recognizes three levels of causality corresponding to immediate, underlying, and basic determinants of child nutritional status.

The **immediate determinants** of child nutritional status manifest themselves at the level of the individual human being. They 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. In turn, disease depresses appetite, inhibits the absorption of nutrients in food, and competes for a child's energy. Dietary intake must be adequate in quantity and in quality, and nutrients must be consumed in appropriate combinations for the human body to be able to absorb them.

The immediate determinants of child nutritional status are, in turn, influenced by three **underlying determinants** manifesting themselves at the household level. These are food security, adequate care for mothers and children, and a proper health environment, including access to health services. Associated with each is a set of resources necessary for their achievement.

Food security is achieved when a person has access to enough food for an active and healthy life (World Bank 1986). The resources necessary for gaining access to food are food production, income for food purchases, or in-kind transfers of food (whether from other private citizens, national or foreign governments, or international institutions). We know that no child grows without nurturing from other human beings. This aspect of child nutrition is captured in the concept of care for children and their mothers, the latter who give birth to children and who are commonly their main caretakers after they are born. *Care*, the second underlying determinant, is the provision in households and communities of "time, attention, and support to meet the physical, mental, and social needs of the growing child and other household members" (ICN 1992). Examples of caring practices are child feeding, health seeking behaviors, support and cognitive stimulation for children, and care and support for mothers during pregnancy and lactation. The adequacy of such care is determined by the caregiver's control of economic resources, autonomy in decision making, and physical and mental status. All of these resources for care are influenced by the caretaker’s status relative to other household members. A final resource for care is the caretaker’s knowledge and beliefs. The third underlying determinant of child nutritional status, *health environment and services*, rests on the availability of safe water, sanitation, health care and environmental safety, including shelter.

A key factor affecting all underlying determinants is poverty. A person is considered to be in (absolute) poverty when the person is unable to satisfy his or her basic needs—for example, food, health, water, shelter, primary education, and community participation—adequately (Frankenberger 1996). The effects of poverty on child malnutrition are pervasive. Poor households and individuals are unable to achieve food security, have inadequate resources for care, and are not able to utilize (or contribute to the creation of) resources for health on a sustainable basis.

Finally, the underlying determinants of child nutrition (and poverty) are, in turn, influenced by **basic determinants**. The basic determinants include the potential resources available to a country or community, which are limited by the natural environment, access to technology, and the quality of human resources. Political, economic, cultural, and social factors affect the utilization of these potential resources and how they are translated into resources for food security, care and health environments and services.

The conceptual framework of Figure 1 can be usefully placed in the context of a multimember household economic model. The household behaves as if maximizing a welfare function, *W*, made up of the utility functions of its members, indexed $i = 1,...,n$. The household members include a caregiver who we assume is the mother (indexed $i = M$), *D* other adults (indexed $i = 1,...,D$), and *J* children (indexed $i = 1,...,J$). The welfare function takes the form

$$W(U_m^M, U_{ad}^1,...,U_{ad}^D, U_{ch}^1,...,U_{ch}^J; \beta) \qquad \beta = (\beta_m^M, \beta_{ad}^1,...,\beta_{ad}^D)\ , \tag{1}$$

where the U^i are the members' utility functions, and the βs represent each adult household member's "status." Such status affects the relative weight placed on members' preferences in overall household decisionmaking, or their decisionmaking "power." The utility functions take the form

$$U^i = U(N, F, X_o, T_L) \quad i = 1,...,n = 1 + D + J\ , \tag{2}$$

where N, F, X_o and T_L are 1 x N vectors of the nutritional status, food and nonfood consumption, and leisure time of each household member.

Nutritional status is viewed as a household provisioning process with inputs of food, nonfood commodities and services, and care. The nutrition provisioning function for child *i* is as follows:

$$N_{ch}^i = N(F^i, C^i, X_N^i; \xi^i, \Omega_{HEnv}, \Omega_{Food}, \Omega_{NEnv}) \ i = 1,...,J \tag{3}$$

where C^i is the care received by the *i*th child, and X_N^i represents nonfood commodities and services purchased for caregiving purposes, such as medicines and health services. The variable ξ^i serves as the physiological endowment of the child (his or her innate healthiness). The variable Ω_{HEnv} represents the availability of safe water, sanitation, and health services in the household's community, i.e., the health environment. The variable Ω_{Food} represents the availability of food in the community. Finally, the variable Ω_{NEnv} represents the characteristics of the community's natural environment, such as agroclimatic potential, soil fertility, and water stress level.

The child's care, C^i, is itself treated as a child-specific household-provisioned service with the time input of the child's mother, T_c^i. The mother's decisionmaking process in caregiving is assumed to be governed by the following functions:

$$C^i = C(T_c^i, N_m; E^M, \Omega_C) \quad i = 1,...,J, \tag{4a}$$

$$N_m = N(F^M, C^M, X_N^M; \xi^M, \Omega_{HEnv}, \Omega_{Food}, \Omega_{NEnv}, \beta). \tag{4b}$$

In equation (4a), E^M is the mother's educational level (assumed to be contemporaneously exogenous), which affects her knowledge and beliefs. The term Ω_C represents cultural factors affecting caring practices. N_m is the mother's own nutritional status, embodying the status of her physical and mental health. In addition to the variables entering into the child nutrition provisioning function, the mother's nutritional status may be determined by β, embodying her status relative to other adult members. In this context, the variable reflects the relative value placed on the mother's well-being both by other household members and herself, the latter as reflected in her self esteem.

The maximization of equation (1) subject to equations (2), (3), and (4a,b) along with household members' time and income constraints leads to the following reduced-form equation for the *i*th child's nutritional status in any given year:

$$N_{ch}^{i^*}(\beta, \xi^1,...\xi^J, \xi^M, \Omega_{HEnv}, \Omega_{Food}, \Omega_{NEnv}, \Omega_C, E^M, P, I) \quad i = 1,..., J, \tag{5}$$

where P is a vector of prices of X_0, X_N, F, and I is the household's total (exogenous) income.

Equation (5), a representation of household and individual behavior, can be used to guide the selection of some variables at the national level that are important determinants of children's nutritional status. These are women's relative status (β), health environment (Ω_{Henv}), food availability (Ω_{Food}), characteristics of countries' natural environments (Ω_{NEnv}), cultural norms affecting caring practices (θ_C), women's education (E^M), and real household and national incomes (represented by I and P).

3. REVIEW OF PAST CROSS-COUNTRY STUDIES

A number of cross-country studies of the determinants of child malnutrition and related health outcomes have been carried out over the last five years. In this section we review three that address the determinants of health (an immediate determinant) and six that directly address child malnutrition. The goal is to give a broad overview of their findings with respect to the causes of child malnutrition and to identify limitations that can be overcome in the present analysis. The studies and their findings are summarized in Tables A1 and A2 of Appendix 1. Before moving on, it is useful to consider the merits and demerits of cross-country studies.

GENERAL ISSUES CONCERNING CROSS-COUNTRY STUDIES

Cross-country studies are a useful complement to within-country case studies mainly because they exploit the fact that some variables that might be important determinants of child nutrition, such as democracy and women's status, may exhibit greater variation between countries than within them. Other variables may only be observed at a national level, for example, national food supplies and incomes. In addition, the use of cross-country data for multivariate analysis identifies weaknesses in data series that might not be identified through the casual observation of trends and two-way tables. It thus generates a demand for improvement in data quality. Finally, cross-country analysis can provide a basis for establishing policy priorities on a regional and global basis.

Several concerns regarding cross-country studies have been raised.[2] First, the quality and comparability of the data themselves have been questioned. Data on different variables may come from different agencies, each of which has its own quality standard and sampling frame. Moreover, variable definitions may not be uniform across countries. For example, the definition of "access to safe water" may be different between Egypt and Ghana. A second concern is that data availability problems are more pronounced at the national level than they are for household-level analysis. Studies must often employ available data as proxies for variables for which one would like to employ a more direct measure.

A third concern regarding cross-country studies relates to their subnational applicability. Child malnutrition is an inherently individual and household-level phenomenon. Can cross-country data be used to make inferences about household and individual behavior? An implicit assumption is that a country represents a "representative citizen." But the use of average data can be misleading if distribution is important and differs across countries (Behrman and Deolalikar 1988). Similarly, results arrived at through the use of cross-national data may not be applicable to individual countries' situations, yet it is at the country (and subnational) levels that many policy decisions are made. This factor is claimed to be exacerbated by the fact that all countries are given equal weight in a cross-country regression analysis, yet many countries' populations are hundreds of times smaller than, for instance, China's and have populations that vary widely in their characteristics and behaviors.

Finally, some variables that are exogenous at a household level must be treated as endogenous at the national level since they reflect choices of national policy makers. For example, while putting into place health infrastructure may reduce child malnutrition, governments may also purposefully target infrastructure expansion programs to areas with high malnutrition. Thus addressing endogeneity concerns is particularly crucial in

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[2] Many of the concerns expressed about cross-country studies are concerns that will plague any study employing cross-sectional data. These include (1) the lack of a theory that is specific enough to determine which variables belong in the regression equation (Sala-I-Martin 1997), (2) the general problems with making inferences from cross-section data in that the counterfactual is never observed (Przeworski and Limongi 1993), and (3) the diminished ability to control for confounding variables (Pritchett and Summers 1996). Fortunately in the area of malnutrition, good conceptual models are available to minimize problems related to model specification. In addition, econometric techniques—techniques we employ in this study—are available to account for problems of confounding variables. The issue of drawing inferences from cross-sectional data is a profound one and is a limitation that we, along with all other researchers who use cross section data, have to acknowledge and respect.

cross-national studies (Behrman and Deolalikar 1988). Due to data scarcities, however, it is particularly difficult to do so and most often not done.

The quality of the data employed in this study is discussed in Section 4. Care has been taken to use only the best data available to construct variables that as far as possible measure the key variables in our conceptual framework. In Section 5, we discuss the issue of using different regression weights for countries based on their population size and the steps we take to address endogeneity issues. On the concern about subnational applicability, we can only remark that cross-country studies, while often based on aggregated household-level data, are intended to capture broad global and (for some studies) regional trends. Readers must keep in mind that at the household level, there may be wide variation within countries; policies and programs targeted at a subnational level will have to be formulated with these differences in mind. The same can be said of the concern about the applicability of the results to individual countries.

PAST STUDIES OF THE DETERMINANTS OF HEALTH AND CHILD MALNUTRITION

The main determinants examined in the cross-country health determinants literature are national incomes, poverty, education, and the state of countries' health environments, including service availability. The outcome variables of interest are measures of life expectancy and premature mortality.

Anand and Ravallion (1993) seek to answer the question of how health is affected by per capita national income levels, poverty, and the public provision of social services. National income is measured as Gross Domestic Product (GDP) per capita and poverty as the proportion of a countries’ population consuming less than one dollar a day. Both measures are reported in U.S. dollars arrived at through purchasing power parity (PPP)-adjusted exchange rates to improve cross-country comparability. The public provision of social services is measured as public health spending per capita. The authors find a strong simple correlation between national income and life expectancy for 86 developing countries in 1985. Using ordinary least squares (OLS) regression techniques for a subsample of 22 countries for which they have comparable data, they add poverty incidence and public health spending per person as explanatory variables. They find that the significant, positive relationship between life expectancy and national income vanishes entirely once poverty and public health spending are controlled for. Poverty has a significant negative effect on life expectancy; public health spending, a significant positive effect. A similar result is found by the authors for infant mortality. The authors conclude that "average income matters, but only insofar as it reduces poverty and finances key social services" (p. 144).[3] They find that one-third of national incomes' effect on life expectancy is through poverty reduction and two-thirds through increased public health spending.

Subbarao and Raney (1995) focus on the role of female education using a sample of 72 developing countries and data over the period 1970 to 1985. Employing OLS regression, they regress infant mortality rates (IMR) in 1985 on female and male gross secondary school enrollment ratios lagged five and ten years, GDP per capita (PPP-adjusted), rates of urbanization, a family planning services score,[4] and a proxy variable for health service availability, population per physician. They find that female education has a very strong influence on infant mortality rates (IMRs). Per capita national income, family planning services, and population per physician are statistically significant, but are not as powerful factors as female education. The authors estimate that, for a typical poor country, a doubling of female education in 1975 would have reduced IMR in 1985 from 105 to 78. In comparison, halving the number of people per physician would have reduced it by only 4 points (from 85 to 81) and a doubling of national income per capita would have lowered it by only 3 (from 102 to 99).

Neither of the above two studies test for the possibility that a country's income itself may be affected by the health of its citizens. The OLS regression technique employed also does not account for any omitted country-specific effects that may influence health outcomes and be correlated with the included explanatory variables. They thus risk identifying a merely associative rather than causative relationship between the dependent and explanatory variables of interest.

Pritchett and Summers (1996) take the income question a step further by applying econometric techniques that detect and account for any possible spurious association or reverse causation between health and income. Using data from 1960 to 1985 for between 58 and 111 countries (depending on the estimation technique employed), they examine the impact of GDP per capita ($PPP) and education levels on infant mortality, child

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[3] In a later study, Bidani and Ravallion (1997) use data on 35 developing countries to estimate a random coefficients model of life expectancy and infant/perinatal mortality rates on the distribution of income (breaking countries' populations into groups of "poor" and "nonpoor"), public health spending, and primary schooling. They find poverty to be an important determinant of health and that public health spending and primary school enrollment matter, but more for the poor than the nonpoor.

[4] This score is based on several factors, including community-based distribution of family planning services, social marketing, and number of home-visiting workers.

mortality, and life expectancy. They "eliminate" possible spurious correlation by controlling for country-specific, time invariant factors (e.g., climate and culture) using a first-difference approach. They control for possible reverse causation between income and the outcome variables by employing instrumental variables techniques, using a variety of instruments for income, for example, countries' terms of trade and investment rates. For all regressions, the authors find a significant and negative impact of income on infant mortality. The results are similar for other dependent variables used, such as child mortality rates, but weaker for life expectancy. They conclude that "increases in a country's income will tend to raise health status" (p. 865), estimating a short-run (five year) income elasticity of -0.2 and a long-run (thirty year) income elasticity of -0.4. Education was also found to be a significant factor in improving health status.

Most of the explanatory variables considered in cross-national studies of child malnutrition are the same as for health outcome studies: per capita national incomes, female education, and variables proxying for health service provisioning. Almost all studies also include food available for human consumption as an explanatory variable, measured as daily per capita dietary energy supply (DES) derived from food balance sheets. The dependent or outcome variables employed are the prevalence of underweight or stunted[5] children under five.

A study undertaken by the United Nations Administrative Committee on Coordination's Subcommittee on Nutrition (UN ACC/SCN 1993) examines the determinants of underweight prevalence for 66 developing countries from 1975 to 1992.[6] The study includes several countries for which data are available for more than one point in time, giving a total number of observations of 100. Applying OLS regression, it finds that DES (especially for South Asia), female secondary education, and government expenditures on social services (health, education and social security) are all negatively and significantly associated with underweight prevalence. Regional effects, accounted for using dummy variables, are found to be statistically significant and especially large for

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[5] A child under five is considered stunted if the child falls below an anthropometric cutoff of -2 standard deviations below the median value of height-for-age, using National Center for Health Statistics/World Health Organization standards.

[6] Note that this study was undertaken with the primary aim of developing an estimating equation with the best predictive value. Nevertheless, the estimation results identify variables, some of which may be causal factors, that are statistically associated with child underweight rates.

South Asia. This suggests that factors specific to South Asia that are not accounted for in the analysis are partly responsible for its high malnutrition prevalence.

A later UN ACC/SCN (1994) study focuses specifically on the role of per capita income growth in determining annual changes in underweight prevalences for 42 developing countries from 1975 to 1993. The study finds a statistically significant relationship between GDP per capita[7] growth and changes in underweight prevalence, with a one point increase in the growth rate of the former leading in general to 0.24 of a percentage point decrease in the underweight prevalence annually. Given an average annual reduction in the underweight prevalence rate over the study period (estimated from the reported regional averages) of 1.5, this is a fairly large effect. The study concludes, however, that "although economic growth is a likely factor in nutritional improvement, the deviation from the rate expected is substantial and important" (p. 4), suggesting that other factors are important as well. Gillespie, Mason, and Martorell (1996) extend the UN ACC/SCN analysis to include consideration of a role for public expenditures on social services and food availabilities. Using a subset of 35 countries in the original data set, they find that *levels* of public health and education expenditures (measured in proportion of total government budgets) are significant determinants of changes in underweight prevalences, but that both levels and changes in food availability are not.[8]

Rosegrant, Agcaoili-Sombilla, and Perez (1995)[9] use data from 61 developing countries to regress underweight prevalences on DES, percentage of public expenditures devoted to social services (health, education, and social security), female secondary education and, to proxy for sanitation, the percentage of countries' populations with access to safe water. The data employed are predicted underweight rates for 1980, 1985, and 1990 generated by the UN ACC/SCN (1993) study. The data over these time periods were pooled and OLS regression techniques were applied. The study found DES and social expenditures to be significantly (negatively) associated with underweight rates, but

[7] It is not clear whether the GDP growth rates utilized are estimated using PPP-adjusted exchange rates or using levels data generated by the traditional World Bank atlas method.

[8] Note that the "quasi" first differences approach, in which the dependent variable is expressed in changes over time but some or all of the independent variables are not, does not account for country-specific (time invariant) factors as would a pure first differences approach.

[9] As for the UN ACC/SCN (1993) study, the estimations of this study were undertaken with the primary aim of developing an estimating equation with the best predictive value rather than identifying causal relationships.

that female education and access to safe water were statistically insignificant determinants.

Osmani (1997) attempts to explain the "South Asian Puzzle", i.e., why South Asia's child malnutrition rate is so much higher than Sub-Saharan Africa's, despite almost equal poverty rates, higher food availability in South Asia, and comparable levels of public provision of health and sanitation services. The study employs OLS regression to explore the determinants of child stunting for 66 developing countries in the early 1990s. The initial explanatory variables are per capita GDP ($PPP), health services (proxied by population per physician), extent of urbanization, and the female literacy rate. All are found to be important determinants of stunting. A South Asian dummy variable is significant and quite large, indicating (as does UN ACC/SCN 1993), that additional factors explain South Asia's extreme child stunting rates. Under the hypothesis that the presence of relatively high low-birth-weight (LBW) rates are at the root of the South Asian puzzle, this variable is added into a second estimating equation, causing the South Asian dummy variable to lose its significance. In a third estimating equation, the dummy variable is dropped and replaced with the LBW variable. The latter is statistically insignificant in this equation. The author concludes that LBW and factors influencing it—particularly the low status of women in South Asia—are important determinants of stunting. However, since LBW is endogenous (it is partially determined itself by both per capita income and female literacy), the OLS coefficient estimates are likely to be biased, weakening the study's conclusions.

Frongillo, de Onis, and Hanson (1997) examine the determinants of child stunting using data from 70 developing countries in the 1980s and 1990s. They find national income per capita,[10] DES, government health expenditures, access to safe water, and female literacy rates all to be statistically significant factors. In addition to these variables, the study tests for the significance of four others representing countries' socioeconomic and demographic structure: proportions of population urban, proportions of population in the military, population density, and female share of the labor force. It finds none of these variables to be significant determinants of stunting. As for previous studies, regional effects are found to be strong and significant. They are particularly strong for the "Asia" region, which is represented by 17 countries from South Asia, East Asia, and the Near East.

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[10] The paper does not specify whether or not GDP is measured using PPP-adjusted exchange rates.

In conclusion, while suffering from some methodological limitations, the studies reviewed above point to the importance of four key variables as determinants of child malnutrition. These are per capita national incomes, poverty, women's education, variables related to health services and the healthiness of the environment, and national food availability. They present conflicting results, however, with respect to women's education, health environments, and food availability. Anand and Ravallion (1993) and Osmani (1997) suggest that, in addition, poverty and variables affecting birth weight, such as women's status, may be key. The studies also point to the importance of accounting for potential differences across regions, most particularly, that the determinants for South Asia may be different than those for the other regions.

METHODOLOGICAL LIMITATIONS OF PAST CROSS-COUNTRY STUDIES

From a conceptual standpoint, most studies have not taken into account the differing pathways through which the various determinants of child malnutrition influence it. The danger of not doing so is illustrated in the study by Anand and Ravallion (1993). The analysis shows that income affects health mainly through its influence on government expenditures on social services and poverty. When both income and these other variables that income determines are included in the health regression equation, the parameter estimate for income drops substantially in magnitude. This downward bias results not because income is not important, but because its effect is already picked up by the variables it determines. Past studies that have mixed basic, underlying, and immediate determinants in the same regression equation for child malnutrition (quasi reduced-form estimation [Behrman and Deolalikar 1988]) have likely underestimated the strength of impact and statistical significance of determinants lying at broader levels of causality.

The studies reviewed here (with the exception of Pritchett and Summers 1996) also have not addressed the important issue of endogeneity, in particular, correlation between the error term and included explanatory variables. Endogeneity can arise from a number of different sources. The first, mentioned previously, is the presence of reverse causality between child malnutrition and one of the explanatory variables. For example, governments and international development agencies may target programs to improve health infrastructure to countries with high child malnutrition (the problem of endogenous program placement). The second is the omission of important determinants of child malnutrition (whose effects are relegated to the error term) that may be correlated with the included explanatory variables. Cultural factors influencing caring behaviors, for example, are difficult to measure and are typically unobserved, but are very important to nutritional outcomes. Their exclusion can cause widespread omitted variables bias because they may be correlated with included variables like female education (Engle, Menon, and Haddad 1997). The third is the simultaneous determination of child malnutrition and one of the explanatory variables by some third unobserved variable. For example, restrictions on female labor force participation (unobserved) might reinforce women's low status (a potential determinant of child malnutrition) and simultaneously affect child malnutrition through lack of income earned by women. A final source of endogeneity is measurement error in the explanatory variables. If any of these four problems exist, OLS parameter estimates will be biased, leading to inaccuracy in the estimates and error in inferences based on them.

4. DATA AND ESTIMATION STRATEGY

EXPLANATORY VARIABLES EMPLOYED

This study focuses on the underlying and basic determinants of child malnutrition. We consider explanatory variables representing all three of the underlying determinants described in the conceptual framework, food security, care, and health environments. We consider two variables representing the basic economic and political determinants of child malnutrition. We also explore the role of past child malnutrition in influencing current levels. Our choice of these variables is guided by the conceptual framework (Figure 1), the experience of past studies, and data availabilities. We are unable to include poverty in the analysis due to scarcity of data.

UNDERLYING DETERMINANT VARIABLES

Unfortunately no cross-national data on *food security* from nationally-representative household survey data are available. However, data do exist for one of its main determinants: **national food availability**. We employ this variable as a proxy recognizing that it does not account for the important problem of food access, which is also essential for the achievement of food security (Smith et al. 1998).

Similarly, there are no cross-national indicators of *maternal and child care* that cover the time span of our study. We choose **women's education** and **women's status relative to men** as our two proxies for this factor. The education level of women—the main caretakers of children—has several potential positive effects on the quality of care. More educated women are more capable of processing information, acquiring skills, and modeling positive caring behaviors. They tend to be better able to use health care facilities, including interacting effectively with health care providers and complying with treatment recommendations, and to keep their living environment clean. Finally, more educated women tend to be more committed to child care and interactive and stimulating in their child care practices. On the negative side, education increases women's ability to earn income, increasing the opportunity cost of their time, which tends to mitigate against some important caregiving behaviors, for example, breast-feeding (Engle, Menon, and Haddad 1997).

With respect to women's status, low status restricts women's opportunities and freedoms, giving them less interaction with others and opportunity for independent behaviors, restricting the transmission of new knowledge, and damaging self-esteem and expression (Engle, Menon, and Haddad 1997). It is a particularly important determinant of two resources for care: mothers' physical and mental health and their autonomy and control over resources in households. The physical condition of women is closely associated with the quality of caring practices, starting even before a child is born. A woman's nutritional status in childhood, adolescence, and pregnancy has a strong influence on her child's birth weight (the best single predictor of child malnutrition) and subsequent growth (Martorell et al. 1998; Ramakrishnan, Rivera, and Martorell 1998). A woman who is in poor physical and mental health provides lower quality care to her children after they are born, including the quality of breast-feeding. In general, when the care of a child's mother suffers, the child's care suffers as well (Ramalingaswami, Johnsson, and Rohde 1996; Engle, Menon, and Haddad 1997). While women are more likely to allocate marginal resources to the interests of their children than are men, the lower their autonomy and control over resources, the less able they are to do so (Haddad, Hoddinott, and Alderman 1997; Smith and Chavas 1997). In short, low status restricts women's capacity to act in their own and children's best interests. Much work indicates that it is women's status relative to men (rather than their absolute status) that is the important factor, especially for resource control in households (Haddad, Hoddinott, and Alderman 1997; Smith 1998a; Kishor and Neitzel 1996). We thus choose a measure of women's *relative* status.

Note that women's education and relative status also play a key role in household food security. In many countries women are highly involved in food production and acquisition. The household decisions made in these areas are influenced by women's knowledge regarding the nutritional benefits of different foods and their ability to direct household resources towards food for home consumption (Quisumbing et al. 1995). Thus the effect of women's education and relative status on child malnutrition will partially reflect influences on food security as well as mother and child care.

For *health environment and services,* we utilize a measure of **access to safe water**. Improvements in water quantity and quality have been shown to reduce the incidence of various illnesses, including diarrhea, ascariasis (roundworm), dracunculiasis (guinea worm), schistosomiasis, and trachoma (Hoddinott 1997). We have chosen this variable as a proxy variable for health environment and services because it is the variable for which the most data are available and because it is highly correlated with other measures of the quality of countries' health environments and services (see below).

BASIC DETERMINANT VARIABLES

To broadly capture the resource availabilities of countries, we employ a measure of **per capita national income**. We hypothesize that income plays a facilitating role in all of the underlying factors we have considered. It may enhance health environment and services as well as female education by increasing government budgets. It may boost national food availability by improving resources available for purchasing food on international markets and, for countries with large agricultural sectors, reflects the contribution of food production to overall income generated by households. It may improve women's relative status directly by freeing up resources for improving women's lives as well as men's. Finally, there is a strong negative relationship between national incomes and poverty, as shown by a plethora of recent studies (e.g., Deininger and Squire 1996; Roemer and Gugerty 1997).

We account for the political context within which child malnutrition is determined by using **democracy** as an indicator. As for national income, we hypothesize that democracy plays a facilitating role in all of the underlying factors considered. The more democratic a government, the greater the percentage of government revenues that may be spent on education, health services, and income redistribution. A more democratic government may also be more likely to respond the needs of *all* of its citizens, women's and well as men's, indirectly promoting women's relative status. With respect to food security, the work of Drèze and Sen (1989) and others clearly points to the expected importance of democracy in averting famine. More democratic governments may be more likely to honor human rights—including the rights to food and nutrition (Haddad and Oshaug 1998)—and to encourage community participation (Isham, Narayan, and Pritchett 1995), both of which are important to overcoming child malnutrition.

The estimation technique we employ allows us to explicitly consider only observed variables that change over time. However, we are able to implicitly control for unobserved time-invariant factors (see the section on estimation strategy below) that affect child malnutrition as well. Some important determinants of child malnutrition identified in the last section fall into the latter category, for example, climate and sociocultural environments.

PAST CHILD MALNUTRITION

It is well established that a child's current nutritional status is conditioned by its preceding nutritional status, particularly for age-based indicators such as stunting and underweight. In addition, we know that malnutrition in childhood has important long-term effects on the work capacity and intellectual performance of adults (Martorell 1997). Recent studies have also pointed to the existence of an intergenerational effect of child malnutrition, showing that women who were malnourished as children are more likely to give birth to low-birth-weight children, regardless of current environmental factors (Rivera et al. 1996). At a country level, therefore, past prevalences of child malnutrition—regardless of current environmental factors—are likely to have an independent, numerically positive, effect on current prevalences.

THE DATA

The analysis is based on data for 63 developing countries over the period 1970-1996. Our dependent variable is prevalence of children under five who are underweight for their age. The availability of high-quality nationally-representative child underweight survey data is the limiting factor for inclusion of countries. Data for the explanatory variables are matched for each country by the year in which the underweight data are available. For statistical reasons (see next section), only countries for which child malnutrition data are available for at least two points in time are included. The total number of country-year observations is 179.

The countries covered, classified by region, are listed in Table 2. For each country, the years covered are given in parentheses. The average number of observations per country is 2.8. The average number of years between observations for a country is 6.9. Over half of all countries in South Asia, Sub-Saharan Africa, East Asia, and Latin America and the Caribbean are included in the sample. The Near East and North Africa region, for which only 5 of 16 countries are included, has the poorest coverage (see Appendix Table A8 for regional grouping of developing countries). Overall, the sample covers 53 percent of the developing countries and 88 percent of the 1995 population of the developing world. While the data have not been purposefully sampled in a random manner, we believe that they are adequately representative of the population of developing countries.[11]

The data are compiled from various secondary sources. The measures employed for the explanatory variables, their definitions, and sample summary statistics are given in Table 3. Here a brief description is given for each. All numbers in the data set and their sources as documented by variable, country, and year are provided in Appendix 2. The construction of a complete data set (containing no missing values) and full use of the available data necessitated estimation of values for a small number of observations on the explanatory variables (2 percent) using first-order regression techniques (Haddad et al. 1995).

Child Malnutrition

As indicated above, for child malnutrition we utilize a measure of the prevalence of underweight children under five (*CHMAL*). The criteria we use for identifying an underweight child is that the child's weight-for-age be more than 2 standard deviations below the median based on National Center for Health Statistics/World Health Organization standards. This measure represents a synthesis of height-for-age (identifying long-term growth faltering or stunting) and weight-for-height (identifying acute growth disturbances or wasting).[12] The large majority of the data, 75 percent, are from the World Health Organization's Global Database on Child Growth and Malnutrition (WHO 1997). These data have been subjected to strict quality control standards for inclusion in the database.

The criteria for inclusion of surveys in the WHO Global Database are

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[11] It is possible that countries with low rates of child malnutrition and high incomes are more able to conduct national surveys of malnutrition. In this case these countries would be overrepresented in our sample. However, it is equally likely that national-level malnutrition surveys are carried out in low-income countries with high rates of malnutrition due to the increased interest by institutions with external funding sources.

[12] National-level data on stunting and wasting are becoming increasingly available and more widely-employed as indicators of child malnutrition (see UN ACC/SCN 1997 for the first review of trends in stunting, for example). Future cross-country panel data studies of the causes of child malnutrition will be able to use both of the indicators, which are likely to have different determinants (Victora 1992; Frongillo, de Onis, and Hanson 1997).

- a clearly defined population-based sampling frame, permitting inferences to be drawn about an entire population;
- a probabilistic sampling procedure involving at least 400 children;
- use of appropriate equipment and standard measurement techniques; and
- presentation of data in the form of Z-scores in relation to the NCHS/WHO reference population (WHO 1997).

A second source of the data, 17 percent, is the United Nations Administrative Committee on Coordination-Subcommittee on Nutrition (UN ACC/SCN 1992, 1996), which is felt to be of adequate quality. A third source of the data, 7 percent, is the *World Development Indicators* (World Bank 1997a), for which the quality of data is unsure based on our earlier experience in using it. We subjected all of the data to tests for potentially erroneous values and, subsequently, discarded several observations from the latter source.[13] Where data are reported for under-three-year-olds rather than under-five-year-olds (12 percent of the data points), we converted the data to under-five-year-old equivalents based on a technique employed in UN ACC/SCN (1993) (see Appendix 2).

Per Capita National Food Availability

For national food availability we employ countries' daily per capita dietary energy supplies (DES). This measure is derived from food balance sheets compiled by the United Nations Food and Agriculture Organization (FAO) from country-level data on the production and trade of food commodities. Given data on seed rates, wastage, stock changes, and types of other utilization of food commodities (e.g., animal feed), a supply account is prepared for each commodity in terms of the weight available for human consumption each year. Total energy availability is then estimated by converting the weights of each commodity into energy values and aggregating the energy values across commodities. The aggregate energy supply is then divided by the population size to

[13] We employed a "DFFITS" procedure (Haddad et al. 1995) to detect observations with unusually large or small values for the dependent variable or for one of the explanatory variables relative to the other variables used in the analysis. We checked each detected observation thoroughly for error by examining how well they conformed with other data in near-by years and checking with alternative sources. As a result of this procedure, we excluded four countries from the sample for which at least one (of the two necessary) data point was from World Bank (1997a)—Botswana, the Central African Republic, Paraguay, Iran—as well as 1970 data points for Côte d'Ivoire and Nigeria. No original source was reported for these data, and their values could not be justified through comparing with other data or sources.

arrive at per capita DES. The data employed were obtained from FAO's FAOSTAT database (FAO 1998).

Women's Education

For women's education, we employ female gross secondary school enrollment rates (*FEMSED*) as a proxy measure for female education at all levels up to and including the secondary level. The variable is defined as total female enrollment in secondary education, regardless of age, expressed as a percentage of the population age-group corresponding to national regulations for education at the secondary level. The data are from the United Nations Educational, Scientific and Cultural Organization's UNESCOSTAT database (UNESCO 1998).

Women's Relative Status

There is no agreed upon measure of “women’s status." Most measures available in the literature are multiple-indicator indices (e.g., UNDP 1997; Kishor and Neitzel 1996; Mohiuddin 1996; Ahooja-Patel 1993), which are vulnerable to charges of arbitrariness in composition and aggregation method (Deaton 1997). As discussed above, we have chosen women's status relative to men rather than their absolute status as our explanatory variable. The proxy measure we employ is the ratio of female life expectancy at birth to male life expectancy at birth (*LFEXPRAT*). Life expectancy at birth is defined as the number of years a newborn infant would live if prevailing patterns of mortality at the time of his or her birth were to stay the same throughout his or her life. The extension of human life reflects the intrinsic value of living as well as being a necessary requirement for carrying out a variety of accomplishments (or “capabilities”) that are generally positively valued by society. It is associated with an enhanced quality of life. Inequalities in this variable favoring males reflect discrimination against females (as infants, children, and adults) and entrenched, long-term gender inequality (Sen 1998; Mohiuddin 1996).[14] We believe that the ratio it is a good proxy indicator of the cumulative investments in females relative to males throughout the human life cycle. The source for life expectancy data is the *World Development Indicators* (World Bank 1998a).

[14] Much of the discrimination against females occurs in early childhood, but some also occurs in the main child-bearing age group of 15-44 years (Osmani 1997).

Access to Safe Water

The measure we employ is the percentage of countries' populations with access to safe water (SAFEW), defined as the population share with reasonable access to an adequate amount of water that is either treated surface water or water that is untreated but uncontaminated water (such as from springs, sanitary wells and protected boreholes). An adequate amount of water is that needed to satisfy metabolic, hygienic, and domestic requirements, usually about 20 liters per person per day (World Bank 1997b). This measure is used to proxy the broad dimensions of countries' health environments, including access to sanitation and health care (for which insufficient data exist for our use), in that measures of these variables are highly correlated with our measure[15]: countries with high safe water access are likely to have good health environments and services overall. The data are from various issues of UNICEF's *State of the World's Children* and the World Health Organization (WHO 1996).

Our measure of access to safe water is the one for which we have the most concern regarding data quality. In particularly, walking distance or time from household to water source is the principle criterion used for assessing safe water access, but the definition varies across countries (WHO 1996). We partially account for this problem in the regression estimations by controlling for country-specific attributes (see Section 4.3). We have also been particularly careful to detect and investigate outliers for the variable and to construct tests for endogeneity caused by measurement error.

Per Capita National Income

For per capita national income, we employ real per capita Gross Domestic Product (GDP) expressed in purchasing power parity (PPP)-comparable 1987 U.S. dollars. 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

[15] The Pearson's correlation coefficient between *SAFEW* and the measure "population with access to sanitation" is 0.63 (p = .000, with 114 observations). That between *SAFEW* and the measure "population with access to health care" is 0.59 (p = .000, with 92 observations). We do not employ the widely-reported measure "population per physician" as we do not feel that this variable reflects the quality of health environments of the types of poor households likely to have malnourished children living in them.

traded internationally. The data are from the World Bank's *World Development Indicators* (World Bank 1998a).[16]

Democracy

For degree of democracy (*DEMOC*), we employ an average of two seven-point country-level indices from Freedom House (1997), one of political rights and one of civil liberties, giving each an equal weight. Political rights enable people to participate freely in the political process, including choosing their leader freely from among competing groups and individuals. Civil liberties give people the freedom to act outside of the control of their government, including to develop views, institutions and personal autonomy (Ryan 1995). The combined index ranges from 1 to 7, with "1" corresponding to least democratic and "7" to most.

ESTIMATION STRATEGY

We begin by hypothesizing that our dependent variable, child malnutrition (CM), is determined by K explanatory variables, denoted X and indexed by $k = 1,...,K$. We assume that the basic model relating these variables takes the form

$$CM_{it} = \alpha + \sum_{k=1}^{K} \beta_k X_{k,it} + u_{it} \quad i=1,...,n;\ t=1,...,T, \tag{7}$$

where i denotes countries, t denotes time, α is a scalar, β is a K x 1 vector of parameters, and u_{it} is an error term. For expository purposes, we assume that all countries' observations are for the same time periods, i.e., that our panel is "balanced."

We first estimate equation (7) by Ordinary Least Squares (OLS). In this case, all of the observations on individual countries and time periods are pooled. The error term u_{it} is assumed to be stochastic and normally distributed with mean zero and constant variance σ^2. The estimating equation is

$$CM_{it} = \alpha + \sum_{k=1}^{K} \beta_k X_{k,it} + u_{it} \qquad u_{it} \sim N(0, \sigma^2). \tag{8}$$

[16] These data are only reported for 1980-present. To arrive at comparable purchasing power parity (PPP) GDP per capita figures for the 1970s data points, it was necessary to impute growth rates from the data series on GDP in constant local currency units and apply them to countries' 1987 PPP GDPs.

With the availability of data at more than one point in time for each country, the opportunity exists to remove any bias in the parameter estimates introduced by unobserved, time-invariant factors that may be correlated with the included explanatory variables. Specifically, we estimate a country fixed-effects (one-way error components) model (Baltaji 1995) that allows us to control for country-specific factors that do not trend upwards or downwards over about 13-year periods, the average time interval covered for a country.[17] The time-invariant factors may be climate, characteristics of countries' physical environments (e.g., soil type and topography), and deeply-embedded cultural and social mores. In addition to removing bias, the fixed-effects approach controls for measurement errors and noncomparabilities in the data due to definitional and measurement differences at the country level (Ravallion and Chen 1996).

The country fixed-effects (FE) model is as follows:

$$CM_{it} = \alpha + \sum_{k=1}^{K} \beta_k X_{k,it} + \mu_i + v_{it} \quad v_{it} \sim N(0, \sigma^2), \tag{9}$$

where the μ_i are unobservable country-specific, time-invariant effects and the v_{it} are stochastic. The actual estimating equation is obtained by transforming the observations on each variable into deviations from the country-specific averages:

$$CM_{it} - \overline{CM}_i = \sum_{k=1}^{K} \beta_k (X_{k,it} - \overline{X}_{k,i}) + (\mu_i - \overline{\mu}_i) + (v_{it} - \overline{v}_i). \tag{10}$$

Since the μ_i terms are time-invariant, $(\mu_i - \overline{\mu}_i) = 0$, and they drop out of the model. Unbiased and consistent estimates of the β_k can be obtained using OLS estimation if the error term does not contain components that are correlated with an explanatory variable. From a practical standpoint, equation (9) can be estimated by including a dummy variable for each country, essentially allowing each country its own intercept term.

Recognizing the differences in levels of causality implied in the conceptual framework, we estimate separate "reduced-form" equations for the underlying determinants (health environment, women's education and status, and national food

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[17] We have chosen a fixed-effects rather than random-effects specification as the latter is applicable only to situations in which the sample is a small random subset of a population. In our case, while there is no reason to believe that the sample is nonrandom, it covers more than half of the population. We also do not believe our sample to differ in any systematic manner from the countries not included in the study. Therefore the fixed-effects approach, in which results are highly dependent on the specific characteristics of the included units, seems most appropriate.

availability) and the basic determinants (national income and democracy) for both OLS and FE estimations. We are then able to explore the ways in which the basic determinants work *through* the underlying determinants to affect child malnutrition.

In each of the estimating equations, if the explanatory variables are correlated with the error term for any of the reasons outlined previously in Section 3 (methodological limitations), then biased estimates will result. We already address this problem in two ways. First, we specify estimating equations in which the hypothesized basic determinants are separated from the underlying determinants. Second, we control for country-specific, time-invariant unobserved factors. We further address the problem by undertaking two tests.

The first is the Ramsey Regression Specification Error Test (RESET) for omitted variable bias (Haddad et al. 1995). To perform this test, we first construct a matrix Z of the second, third, and fourth moments of the fitted values of countries' child malnutrition prevalences from the CM regression equations. We then reestimate the equations including the variables in Z as regressors. If the coefficients on the Z variables are jointly significant, the null hypothesis of no omitted variables bias is rejected.

The second test is the Hausman-Wu instrumental variables (IV) test for statistical endogeneity (Haddad et al. 1995; Davidson and Mackinnon 1993). In the presence of endogeneity of any of the explanatory variables, OLS/FE estimates are inconsistent (assymptotically biased). The Hausman-Wu test determines whether there is a significant difference between OLS/FE parameter estimates and parameters estimated using IV estimation, the latter which are consistent in the presence of endogeneity. The test is undertaken in two steps. First, the potentially endogenous variable is regressed on the remaining (assumed exogenous) variables and a set of "instruments" for it. Such an instrument must satisfy two conditions: (1) it must be a good predictor of the potentially endogenous variable; and (2) it must not be associated with child malnutrition except through that variable.

To test for endogeneity of X_1 in the static FE model (equation 9), for example, given instruments $z_{11},...,z_{1G}$, the estimating equation is

$$X_{1,it} = \gamma_0 + \sum_{k=2}^{K} \gamma_k X_{k,it} + \mu_i + \sum_{g=1}^{G} \gamma_g z_{1g} + \psi_{it}. \qquad \textbf{(11)}$$

In the second step of the test, the dependent variable is regressed on all explanatory variables plus the predicted residuals from the first stage, denoted $\hat{\psi}_{it}$:

$$CM_{it} = \xi_0 + \sum_{k=1}^{K} \xi_k X_{k,it} + \mu_i + \eta\hat{\Psi}_{it} + \Pi_{it}. \tag{12}$$

The null hypothesis that the explanatory variable is not endogenous is rejected if the coefficient on the predicted residuals is statistically significant. In the presence of endogeneity, IV estimates are consistent but not efficient. If there is no difference between the IV and OLS/FE estimates, then the more efficient OLS/FE estimates are preferred. If, however, the IV estimates are significantly different from the OLS/FE estimates, then the IV estimates are preferred.

The credibility of the Hausman-Wu test results rests on our ability to locate proper instruments for the potentially endogenous variables. Before performing the tests, we thus conduct two further tests to find out if candidate instruments are appropriate. The first, a "relevance test," determines whether the selected instruments can in fact explain variation in the potentially endogenous variable to be instrumented (Bound, Jaeger, and Baker 1995). The test is an F test on the joint significance of the instruments in a predicting equation for the potentially endogenous variable. For our example, it is an F test of the joint significance of $z_{11},...z_{1G}$ in equation (11). If the instruments are jointly significant, the null is rejected, and the instruments are considered "relevant." Note that the bias in IV estimates can be approximated by 1/F (where "F" is the F-test statistic) multiplied by the bias from OLS/FE estimation. Hence, if F = 1, the IV estimates are as biased as the OLS/FE estimates.

The second test, an "overidentification test," determines whether the candidate instruments directly affect the dependent variable other than through the potentially endogenous variable to be instrumented (Davidson and Mackinnon 1993). It tests whether the instruments are correlated with the error term from IV estimation. Returning to our FE model example, the test takes place in two steps. In the first, the predicted residuals from a Two-Stage Least Squares regression of the child malnutrition equation, denoted $\hat{\Pi}$ are calculated. In the second step, the predicted residuals are regressed on the exogenous variables and the instruments:

$$\hat{\Pi}_{it} = \theta_0 + \sum_{k=2}^{K} \theta_k X_{k,it} + \mu_i + \sum_{g=1}^{G} \theta_g z_{1g} + E_{it}. \tag{13}$$

The statistic N*R^2, where N is the number of observations, is distributed χ^2 with degrees of freedom equal to the number of instruments minus the number of potentially endogenous variables being tested (in our example, 1). The (joint) null hypothesis tested is that the instruments are uncorrelated with the error term from the child malnutrition equation and the model is correctly specified. This test can only be performed when there is more than one instrument.

If any instrumental variable does not pass the relevance test, then it is not employed for the Hausman-Wu test. If a sufficient number of instruments is available for performing the overidentification test and the test is not passed, then the instrument is not employed. The variables for which we have particular concern with respect to statistical endogeneity are food availability, national income, democracy and safe water access, for which the possibility of reverse causality with child malnutrition exists.[18] For the latter variable, we are also concerned about endogeneity due to measurement error.

Chow F-tests for structural change are performed to determine whether there are significant differences across the developing-country regions in the parameter estimates. The sum of squared residuals (SSR) of a regression including all regions is compared with the sum of the SSR of five separate regressions, one for each region. An F-test is used to determine whether the null hypothesis that the parameter estimates are the same across the regions is rejected. We also conduct five separate tests in which each region is successively removed from the full sample as a comparison group. This latter set of tests helps to determine which particular region(s) is(are) the source of any differences.

Given the limitation of our unbalanced panel, it is not appropriate to estimate a two-way error components model in which period dummies are included in regression equation (9). Nor is it possible to include a time trend as a regressor. This is because any particular year or even group of years (e.g., decade) is not available for all countries in the study. In this case, estimated period effects would not represent the effect of the time period for all countries. Their inclusion would misrepresent the period effects for the sample and population and inappropriately distort the regression coefficients on the substantive explanatory variables.

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[18] We are concerned about reverse causality for safe water access since governments may target safe water programs to areas with high malnutrition. We are concerned about the problem for food availability and national incomes since malnourished people are likely to be less productive food producers and income earners. For democracy the concern is that malnourishment may lead to political instability, an environment not conducive to democratic governance.

However, we can explore some of the dynamics of child malnutrition determination using a reduced sample. We next explore three modifications of the base models that include lagged child malnutrition as a regressor and, where appropriate, a time trend. The first is a simple OLS model. Equation (8) is modified as follows:

$$CM_{it} \;=\; \beta_0 CM_{i,t-1} + \sum_{k=1}^{K} \beta_k X_{k,it} + u_{it} \quad u_{it} \sim N(0,\sigma^2), \qquad \textbf{(14)}$$

where $CM_{i,t\text{-}1}$ is the lagged value of Cm_{it}.

The second dynamic specification is based on a fixed-effects approach. The base estimating equation is as follows:

$$CM_{it} \;=\; \beta_0 CM_{i,t-1} + \sum_{k=1}^{K} \beta_k X_{k,it} + \mu_i + v_{it} \quad v_{it} \sim N(0,\sigma^2), \qquad \textbf{(15)}$$

where ν_{it} is stochastic. Equation (15) cannot be estimated using the standard OLS procedure. If $\beta_0 \neq 0$, $CM_{i,t}$ is a function of the error term, and OLS estimation yields biased and inconsistent estimates. Eliminating this bias requires, first, undertaking a first-difference transformation to wipe out the country fixed-effect term, yielding the following estimating equation:

$$(CM_{it} - CM_{i,t-1}) \;=\; \beta_0 (CM_{i,t-1} - CM_{i,t-2}) + \sum_{k=1}^{K} \beta_k (X_{k,it} - X_{k,i,t-1}) + (\nu_{it} - \nu_{i,t-1}). \qquad \textbf{(16)}$$

Second, the term ($CM_{i,t\text{-}1}$ - $CM_{i,t\text{-}2}$) must be instrumented. The instrumental variable for the term is $CM_{i,t\text{-}2}$ itself, which is correlated with ($CM_{i,t\text{-}1}$ - $CM_{i,t\text{-}2}$) but not with ($\nu_{i,t}$ - $\nu_{i,t\text{-}1}$) (Baltaji 1995).

The third dynamic specification adds to the second a time trend and initial values of the explanatory variables. The base estimating equation is

$$CM_{it} \;=\; \beta_0 CM_{i,t-1} + \sum_{k=1}^{K} \beta_k X_{k,it} + \gamma t + \sum_{k=1}^{K} \theta_k t w_{k,i} + \mu_i + v_{it} \quad v_{it} \sim N(0,\sigma^2), \qquad \textbf{(17)}$$

where the w_i are initial values of the explanatory variables. These terms are interacted with the time trend in order to permit the effect of initial conditions on current child malnutrition to vary over time. A first-difference transformation yields the following estimating equation:

$$(CM_{it} - CM_{i,t-1}) = \beta_0 (CM_{i,t-1} - CM_{i,t-2}) + \sum_{k=1}^{K} \beta_k (X_{k,it} - X_{k,i,t-1}) + \gamma S + \sum_{k=1}^{K} \theta_k w_{k,i} + (\nu_{it} - \nu_i \quad \textbf{(18)}$$

where $S = t - (t\text{-}1)$, i.e., the length of the spell between the time periods. This term allows for uneven spacing of the observations across countries characterizing our unbalanced panel.[19] As for equation (16), the term ($CM_{i,t\text{-}1}$ - $CM_{i,t\text{-}2}$) must be instrumented with $Cm_{i,t\text{-}2}$. Because estimation of equations (16) and (18) requires three observations for each country, the estimations are undertaken with data from only 36 of the sample countries.

Before moving on to the estimation results, we note that the data used in the regression analysis are not population weighted. This is because we wish to use the variation across countries—our unit of analysis—to draw out the relationships between child malnutrition and its determinants. Giving any country more weight than others defeats this purpose because it distorts the variation across countries. Note that we have adequately controlled for the effects of population size in our construction of the explanatory variables where needed, and that the fixed-effects analysis partially controls for large differences in population across countries.

5. ESTIMATION RESULTS: NEW EVIDENCE FROM CROSS-COUNTRY DATA, 1970-1996

DESCRIPTIVE ANALYSIS

Table 4 reports child malnutrition (underweight) rates and means of the explanatory variables by developing region and decade for the study sample. The numbers for the developing countries as a whole are given in Table 5. Figures 2 through 7 show the country-level data itself, plotting child malnutrition prevalences against each variable using data pooled across all countries and time periods. The fitted lines in each figure are arrived at using a Lowess smoothing technique.[20]

The regional trends and levels of child malnutrition in the sample closely follow those for the developing countries as a whole (Table 1). South Asia had the highest prevalence of child malnutrition over the study period, with a rate roughly double that of the next highest region, that of Sub-Saharan Africa (Table 4). Over half of all South

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[19] Note that the usual constant (which is replaced by the term γS) is suppressed.

[20] The Lowess smoother produces locally-weighted regression smoothing using iterative weighted least-squares (SPSS 1993).

Asian children under five were underweight for their age. Roughly one-third were underweight in Sub-Saharan Africa, and one-fifth in East Asia. The Near East and North Africa (NENA) and Latin America and Caribbean (LAC) regions had the lowest underweight rates. The regions whose rates have declined the greatest are South Asia and East Asia. Sub-Saharan Africa is the only region for which underweight rates have increased.

Turning to the underlying-determinant explanatory variables, NENA and LAC had the highest safe water access rates, over 70 percent, while Sub-Saharan Africa had the lowest, at 37.5 percent, illustrating high inequality across the regions (Table 4, column 2). Improvements in access to safe water over the study period have been extraordinary. For the full sample, they more than doubled, starting at 36.3 percent in the 1970s, increasing quickly to 61.6 percent in the 1980s and rising to 69 percent by the 1990s (Table 5). Rates of improvement were the greatest for East Asia and South Asia. Figure 2 illustrates a fairly strong negative association between national rates of access to safe water and child malnutrition, especially after a safe water access rate of 40 percent has been reached.

With respect to women’s education, Sub-Saharan Africa had the lowest female secondary enrollment rate, at 15.6 percent (Table 4, column 3). Not far in front was South Asia, where only 23.8 percent of women had a secondary education. For the full sample, female secondary enrollment rates improved steadily over the study period, rising from 21.7 percent in the 1970s to 45 percent in the 1990s. Nevertheless they remain quite low, with less than half of women in developing countries completing a secondary education. Figure 3 shows the association between female secondary enrollments and child malnutrition rates to be fairly strongly negative, especially when female enrollment rates are very low (below 40 percent).

Our indicator of women's relative status was by far the lowest in South Asia, with female and male life expectancy being roughly equal (Table 4, column 4). Reflecting women's greater innate physiological potential than men's, women's life expectancy in the developed countries is on average six to seven years longer than men's (Mohiuddin 1996). The ratio in Norway, for example, is 1.08. Thus South Asia's ratio of 1.01 is extremely low. Sub-Saharan Africa, East Asia, and NENA had ratios of 1.061, 1.051, and 1.043, respectively, which is still below that common in developed countries. LAC had the highest of the developing country regions, which, at 1.094, is on par with the developed-country level. With respect to changes over time, the ratio increased from 1.024 in the 1970s to 1.047 in the 1990s (Table 5). This change, while small in absolute terms, is equal to about one-eighth of the variable's entire range (0.97 to 1.12—see below—as determined by a mix of behavioral and biological factors). The ratio has improved or remained fairly steady in all regions except Sub-Saharan Africa. Figure 4 exhibits a fairly strong negative association between life expectancy ratios and child malnutrition prevalences for the sample as a whole. The relationship appears very strong at lower life expectancy ratios, where most of the South Asian data points fall, flattening out after about 1.05.

Per capita dietary energy supplies (DES) were the lowest in South Asia and Sub-Saharan Africa over the study period. The minimum daily dietary energy requirement for an active and healthy life is about 2,150 kilocalories (FAO 1996). These regions' *supplies* (not intake) barely surpassed this requirement (Table 4, column 5). The minimum DES considered necessary (but not sufficient) for bringing food insecurity to a very low 2.5 percent of a country's population is 2,770 kilocalories (FAO 1996). The dietary energy supplies of East Asia and LAC neared this level over the study period. NENA's surpassed it. From the 1970s to the 1990s, DES increased in all regions except Sub-Saharan Africa. Figure 5 points to a strong negative association between DES and child malnutrition rates, especially at lower levels of DES.

Per capita national income was the lowest for South Asia and Sub-Saharan Africa over the study period and the highest for LAC (Table 4, column 6). From a descriptive standpoint, Figure 6 indicates a strong negative relationship between per capita national incomes and child malnutrition in developing countries. However, at the extremes there is much less correspondence. Two observations are worth noting. First, above a per capita GDP threshold of $3,000, it is rare to find child underweight rates above 25 percent. Most of the LAC and NENA data points fall into this category. Second, below a per capita GDP of $2000, where most of the Sub-Saharan African and South Asia data points lie, there are striking differences in the prevalences. While high income and high child malnutrition generally do not coexist, it is possible—and common—for countries to achieve low child malnutrition prevalences even with low per capita incomes. Some countries in our sample for which this is the case are Côte d'Ivoire (in 1986), Lesotho (in 1981), Nicaragua (in 1993) and Zimbabwe (1994).

The region that has been least democratic over the study period is East Asia (Table 4, column 7). Interestingly, South Asia and LAC, while at opposite extremes in terms of underweight rates, appear to have been roughly equally democratic over the 25-year period. These regions had the highest democracy index scores. Democracy has improved for South Asia, Sub-Saharan Africa, and LAC; it has deteriorated for East Asia and

NENA. It is the only explanatory variable that has declined for the developing-country sample as a whole, falling from about 4 in the 1970s to 2.7 in the 1990s (Table 5). Figure 7 exhibits wide variation within regions about the regional means reported in Table 4 and a distinct negative association between democracy and underweight rates, especially at the extremes.

Recent regional poverty prevalences from Ravallion and Chen (1996) are reported for reference in Table 6. The rate is highest for South Asia—in 1993, almost 45 percent of its population lived in poverty. Sub-Saharan Africa is not far behind, with a 1993 rate of about 40 percent. NENA has the lowest rate. In terms of changes over time, poverty rates have decreased slightly over the 1987 to 1993 period in all regions except for Sub-Saharan Africa and LAC.

MULTIVARIATE ANALYSIS

The descriptive analysis of the last section would lead us to believe that improvements in all of the hypothesized determinants lead to reductions in child malnutrition. However, the bi-variate relationships identified may mask the variables' confounding influences. The goal of this section is to single out the independent effects of changes in each variable while controlling for changes in the others. In the section below, we present the parameter estimates for the static models and the results of the specification tests, we discuss the practical significance of the parameter estimates, and we investigate whether there are significant regional differences. In the next section, the determinants of child malnutrition are explored from a dynamic perspective.

Estimation Results for Static Models

Parameter estimates. Table 7 contains the ordinary least squares (OLS) and country fixed-effects (FE) estimation results when all independent variables are assumed to enter into equations (8) and (9) linearly. Tests for nonlinearities in the FE estimating equations (to be described below) reveal a curvilinear relationship between child malnutrition prevalence and two variables: per capita dietary energy supply (DES) and per capita Gross Domestic Product (GDP). The estimation results when these relationships are taken into account are given in Table 8. The final preferred estimates are those generated using FE estimation and three-segment linear splines to represent the CM-DES and CM-GDP relationships. Nevertheless, we present and discuss the other estimations to demonstrate a number of methodological points.

We first compare the OLS and FE estimation results in Table 7. The underlying-determinant model estimates are given in columns (1) and (3). Those for the basic-determinants model are given in columns (2) and (4). The only difference between the OLS and FE estimating equations is the inclusion of 63 country-specific dummy variables in the latter. F-tests for the joint significance of the dummy variables strongly reject the null hypothesis that they have no impact on child malnutrition.

A comparison of the OLS and linear FE parameter estimates points to some important differences. For the underlying-determinant specifications, once the country fixed-effects terms are included, the magnitudes of the coefficients on safe water access (SAFEW), the female-to-male life expectancy ratio (LFEXPRAT), and DES drop substantially, and they lose statistical significance. This finding indicates that OLS estimates of the effects of these variables on child malnutrition are biased upwards. Second, while the OLS estimates suggest that the effect of FEMSED is statistically insignificant and small, the FE results indicate strong statistical significance and a much stronger effect (the coefficient on FEMSED is 150 percent higher). OLS estimates of the effects of female education are thus biased downward. For the basic-determinant specifications, the OLS coefficient estimate for GDP is biased upwards; that for democracy (DEMOC) is biased downwards. These differences illustrate the strong biases that result when unobserved country-specific, time-invariant factors are omitted from regression analysis of the determinants of child malnutrition.

Column (5) of Table 7 contains FE estimation results when both underlying and basic determinants are included in the same estimating equation. While the parameter estimates of the underlying determinants and DEMOC differ little from the FE separate-model estimates, the magnitude of the coefficient estimate for GDP declines substantially and becomes statistically insignificant. The mixed-model specification would suggest a weak relationship between national income and child malnutrition. The separate-model specification, on the other hand, suggests a statistically significant and practically strong relationship. These contrasts illustrate the dangers in combining variables at very different levels of causality in the same regression.

Starting from the FE models, tests for the significance of all quadratic and interaction terms are undertaken to determine whether any nonlinear relationships between child malnutrition and its determinants exist.[21] No statistically significant interaction terms were detected.[22] However, coefficients on quadratic terms for both DES and GDP are statistically significant and positive, indicating that they work to reduce child malnutrition but at a decreasing rate as they increase. Along with the quadratic, a number of alternative functional forms were fitted to determine which best captures the curvature.

For DES, the quadratic provides a better fit than both reciprocal and linear-log specifications. The estimation results for the quadratic specification are given in column (1) of Table 8. The turning point in the CM-DES curve is 2,727 kilocalories per capita. The result suggests that, after the turning point, increased dietary energy supplies per capita work to *worsen* child malnutrition. The study sample contains 29 data points (mostly in the Latin America and Caribbean and Near East and North Africa regions) that fall above this number. While a declining marginal effect is intuitive, a negative effect is not. To determine whether the upturn is in fact implied by the data rather than forced upon it by the functional form, we next fitted the curve as a linear spline. A search procedure revealed the best fitting spline function to be a three-segment spline with optimal knots at 2,300 and 3,120 kilocalories.[23]

The results of the linear spline estimation for the CM-DES relationship are presented in column (3) of Table 8. The first and second segments of the spline have negative and significant slopes, with the second having a much smaller slope than the first. The last segment has a positive but statistically insignificant slope, suggesting that

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[21] Other available tests of nonlinearities are based on comparisons of subsamples of data across the range of an independent-variable (e.g., Chow F-tests for structural change, Utts Rainbow test, the CUSUM test, see Green 1997; Haddad et al. 1995). Because subsamples of data in our data set do not contain the same countries, the same fixed-effects terms do not apply to them all. Thus the tests are not valid for detecting nonlinearities in country fixed-effects analysis.

[22] Note, however, that microlevel studies have found evidence of significant interactions between the various determinants of child malnutrition, for example, between food security and health (Haddad et al. 1996).

[23] Splines with four or greater segments yield insignificant results due to the small size of our sample. For the three-segment (2 knot) spline, we undertook an extensive grid search using increments of 10 kilocalories to locate the optimal knots in the data, with optimal being the 2-knot combination yielding the smallest sum of squared residuals. Two knots sets proved to fit the data equally well: (2,300, 3,120) and (2,280, 2,940). For both, the coefficients on the third segment were statistically insignificant (n.b. the number of sample data points with DES > 3,120 is 3; the number with DES > 2,940 is 13). We chose the former because it allows more data from the sample to be used for estimations of the coefficients for the usable (first two) segments, thus producing more efficient parameter estimates for them.

the upturn in the quadratic estimation is in fact not statistically significant. The quadratic and spline specifications differ little in terms of overall fit (the sum of squared residuals for the quadratic is 2,157; that of the spline is 2,142). They also differ little in terms of the coefficients on the non-DES explanatory variables. However, their shape differs substantially at high levels of DES, as illustrated in Figure 8a.

As for DES, the quadratic form of the CM-GDP relationship provides a better fit than linear and linear-log specifications. The fit of the reciprocal specification is comparable to the quadratic. The estimation results for the quadratic specification are given in column (2) of Table 8. The turning point in the function is $6,250 (see Figure 8b). Linear spline fitting resulted in a three-segment spline with optimal knots at $800 and $4,750.[24] The estimation results are presented in column (4) of Table 8. As for DES, the first and second segments of the spline have negative and significant slopes, with the second having a much flatter slope than the first. The last segment has a positive (though very small) and statistically significant slope, suggesting the possible existence of a slight upturn in the function after its second knot (Figure 8b).

In addition to the estimated quadratic and spline curves, Figures 8a and 8b show the estimated CM-DES and CM-GDP functions when a linear form is assumed. For the underlying-determinants model, an F-test of the hypothesis that the actual slope of the function is constant is rejected at the 5 percent level. The hypothesis is rejected at the 1 percent level for the basic-determinants model. These results confirm substantial nonlinearity in the CM-DES and CM-GDP relationships.

The parameter estimates derived from the spline specifications in Table 8 columns (3) and (4) are adopted as the preferred estimates for the policy analyses of Sections 6, 7, and 8 below. However, the quadratic estimations are employed for the specification tests of the next section due to substantially increased ease of analysis.

In Figure 8c, the predicted child malnutrition prevalences generated from OLS and the preferred spline-generated FE estimations are plotted against the actual prevalences for the underlying-determinants model. Figure 8d shows the same comparison for the basic-determinants model. As both figures illustrate, the preferred estimates yields much more accurate in-sample predictions than the OLS estimates. The large majority of the difference is due to the inclusion of the fixed-effects terms (rather than the allowance of nonlinearities). It is interesting to note that the data points exhibiting the greatest error in

[24] The grid search for the optimal knots was undertaken for increments of $50.

the OLS estimates relative to the FE estimates are mainly from South Asia.[25] The importance of country-specific, time-invariant factors in influencing child malnutrition in South Asian countries is thus greater than for the other regions, as addressed further below.

According to our conceptual framework (Figure 1) and the mixed/separate-model comparison above, the basic determinants have their impacts on child malnutrition *through* their influence on the underlying determinants. Table 9 gives country fixed-effects regression estimates of the effects of GDP and DEMOC on each underlying determinant, using the quadratic form for the CM-GDP curve. All parameter estimates are statistically significant except that for DEMOC in the FEMSED and LFEXPRAT equations (columns 2 and 3). The significance of these results is discussed below.

Specification tests.

Ramsey RESET Test for Omitted Variables (OV) Bias. The FE basic-determinants model weakly rejects the null hypothesis that the Z matrix proxy variables are zero, i.e., that no OV bias exists. The null hypothesis is rejected at the 5 percent level but not at the 1 percent level. For the underlying-determinant FE model the null hypothesis is not rejected. We conclude that our preferred FE specifications are likely not plagued by serious OV bias, but with more confidence in the underlying-determinant than basic-determinant specification. Note that the OLS basic-determinants model strongly rejects the null hypothesis, suggesting that there is serious OV bias in the parameter estimates. For the underlying-determinant model the null is weakly rejected (at a 5 percent significance level).

Hausman-Wu Tests for Endogeneity of Individual Explanatory Variables. The instrument candidates utilized for the Hausman-Wu tests are given in Table 10. We are able to identify only one instrument each for SAFEW, FEMSED, and LFEXPRAT. Multiple instruments are available for DES and GDP. The rationale for selection of each instrument is given in the table. The instruments arable land per capita (for DES) and economic openness (for GDP) are not significantly correlated with DES and GDP (see last column). They are thus excluded from further testing. We are unable to identify an instrument for DEMOC.

[25] In Figure 8a, the OLS data points exhibiting the greatest error are for Bangladesh (4), India (2), Sri Lanka (2) and Vietnam (1). In Figure 8b, the data points are Bangladesh (4), India (2), Sri Lanka (1), Nepal (1), the Philippines (1), and Guatemala (2).

Table 11 reports the results of the relevance, overidentification, and Hausman-Wu tests for the FE model specifications. The IVs for SAFEW and LFEXPRAT are restricted to small subsamples of the full sample due to data scarcities. The instruments for FEMSED and LFEXPRAT do not pass the relevance test. We thus cannot perform the Hausman-Wu test for these variables. One set of instruments for DES—land in cereal production, fertilizer use and irrigated land—also does not pass the relevance test. Fortunately, another set, that containing only fertilizer use and irrigated land, passes the test at a 5 percent significance level. The instrument for SAFEW (water resources) and the instrument set for GDP (investment share of GDP and foreign investment share of GDP), also pass the relevance test. For all relevant instrument sets, $F>1$. Thus IV estimates, if deemed preferable, would be less biased than the FE estimates.

The overidentification test cannot be performed for SAFEW as only one instrument is available. While we have no statistical evidence that this variable is not correlated with the error term in the CHMAL equation, our intuition suggests that it is not (see "Rationale for Instrument Choice" in Table 10). We thus perform the Hausman-Wu test assuming that the water resource instrument is valid despite its limitations. For DES and GDP, we are restricted to undertaking the test for the linear models in columns (3) and (4) of Table 7.[26] Both sets of instruments easily pass the test: the null hypothesis that the instruments should not be included in the list of original explanatory variables and are not correlated with the error term in the CHMAL equations is not rejected. We assume that the instrument sets satisfy these conditions for the nonlinear model as well, and that they are valid for performing the Hausman-Wu test.

The variables SAFEW, DES, and GDP all pass the Hausman-Wu test (see t-statistics on η in equation (12), reported in column 5). The test results indicate that (1) these variables are likely not endogenous; (2) the direction of causality runs from the variables *to* child malnutrition (and not vice versa), and (3) the FE estimates are not seriously biased by measurement error problems.

In light of these test results, we precede under the assumption that the FE estimates are as accurate as possible given current data constraints. Since SAFEW, DES, and GDP are the variables for which we are most concerned about reverse causality and (in the case of SAFEW) measurement error, we chose to use the more efficient FE estimates rather than IV estimates for the remainder of this analysis. In addition, because the estimations

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[26] The test cannot be performed using the quadratic model because DES and GDP are too highly correlated with their squares.

are based on a sound conceptual framework (Figure 1) and they are undertaken with respect to changes over time in child malnutrition and its determinants, we have no reason to doubt that a causal, rather than merely associative, relationship between child malnutrition and the observed determinants has been identified.

Interpretation of the parameter estimates. Returning to our preferred estimates in column (3) of Table 8, the coefficients on the first three of the hypothesized underlying determinants are statistically significant and negative. Increased access to safe water, increased education of women, and increased relative status of women all work to reduce levels of child malnutrition in developing countries. Increased quantities of food available at a national level also work to reduce levels of child malnutrition in most developing countries. The strength of the effect declines, however, as they increase. According to the data in our sample they have no effect after a DES level of about 3120 kilocalories.

Consider next the basic-determinant results in column (4). The coefficient on DEMOC is negative and statistically significant, suggesting that increased democracy serves to reduce child malnutrition in developing countries. As indicated by the statistically significant and negative coefficients on the first two segments of the GDP linear spline, increased incomes also work to reduce child malnutrition. The strength of the effect declines, however, as they increase. After a level of about $4,725, they no longer contribution to reductions in child malnutrition.

The estimation results in Table 9 aid us in understanding the means through which GDP and DEMOC affect child malnutrition. The coefficient on GDP in all equations is significant and positive. The coefficient on GDP-squared is significant and negative. The results suggest that per capita national income is probably an important resource base for investment—both public and private—in health environments, women's education, women's relative status, and food availabilities. However, the impact of incremental increases in national income tends to decline as incomes rise (as reflected in both quadratic and spline estimation results when CHMAL is the dependent variable). The coefficient on DEMOC is significant and positive in the SAFEW and DES equations. This result suggests that more democratic governments are more likely to direct their budgets to improvements in health environments and food availabilities. They are not more likely to direct public resources towards women's education or to women vis-à-vis men.

How substantial, in a practical sense, are the estimated effects of the determinants on child malnutrition and how do they compare across determinants? In making such comparisons, again, it is important to consider the underlying and basic determinants separately since they lie at different levels of causality. We start with the underlying determinants.

Table 12 column (2) reports elasticities derived from the coefficient estimates of the FE basic- and underlying-determinant child malnutrition regressions. These numbers give the percent reduction in the developing-country child malnutrition prevalence expected from a 1 percent increase in each determinant.[27] Among the underlying determinants, by far the largest percentage reduction in child malnutrition—3.1 percent—is predicted to come from a one percent increase in the variable *LFEXPRAT*. This amounts to a decline in the sample mean rate of 24.6 percent by 0.8 of a percentage point, about two-and-a-half times the annual decline in the last decade. The expected effect is thus quite large. Per capita DES has the next highest elasticity, at -0.95. The elasticity for the first segment of the DES spline function is even higher, while that for the last is zero. The elasticity of *FEMSED* is -0.3. That of *SAFEW* is the lowest among the underlying determinants, at -0.174.

Compared to the elasticities of *LFEXPRAT* and *DES* (for the full sample), those of *FEMSED* and *SAFEW* are quite small. However, the variables are all measured in different units. In comparing the strengths of their effects, attention must be paid to the range of numerical values each actually takes on. These ranges, based on the minimum and maximum values observed among developing countries over the period 1970-95, are given in Table 12, column (3). The ranges for *SAFEW* and *FEMSED* are roughly equal, at about 1-100. The comparison of their elasticities is thus straightforward. However, it is difficult to compare the variable *SAFEW* with *LFEXPRAT*, the latter which takes on values from 0.97 to 1.12. A 1 percent increase in *SAFEW* over the sample mean would raise it from 56.2 percent to 56.8 percent, quite a small change in terms of its 0-100 percent range (only 0.6 of a percent of the range). A 1 percent increase in the variable *LFEXPRAT* over its sample mean (1.062 to 1.071), by contrast, represents 6 percent of its entire range. Thus, while the variable *LFEXPRAT* has a large elasticity and *SAFEW* a

[27] Full sample elasticities for DES and GDP are estimated using (1) a weighted average of regression coefficients for each of the three spline segments, where the weights are the proportion of the sample data points falling into each segment; and (2) sample variable means. Segment-specific elasticities are calculated using segment-specific regression coefficients and segment-specific variable means.

small one, it would take quite a large increase in the former compared to the latter to raise the variable by 1 percent.

Taking this factor into account, the relative strengths of impact of the determinants can be seen from the standpoint of how much an increase in each would be required to bring about the same change in child malnutrition. For example, how much would each have to be increased (holding the others constant) to reduce the malnutrition prevalence by 1 percentage point? These increases are given in Table 12, column (4). They are translated into “scale neutral” numbers that are comparable across variables by calculating each as a percent of its range (column 5).

A 13.1 percentage-point increase in *SAFEW* would be required to bring about a one percentage-point reduction in the child malnutrition prevalence. This represents 13.2 percent of the variable’s range. By contrast, the required increase in *FEMSED* is only 4.6 percentage points, representing only 4.6 percent of its range. Thus the required increase in *SAFEW* to bring about the same reduction in child malnutrition is much higher than the required increase in *FEMSED*. The required increase in *DES* for the full sample (101 kilocalories) is 4.9 percent of its range; that of *LFEXPRAT* (0.0134) is 9.3 percent of its range. Therefore a rough ranking of the underlying determinants in terms of their potency in reducing child malnutrition is: women’s education (greatest potency), followed closely by food availability, in third by women’s relative status and fourth by safe water access. Note that for countries falling into the low *DES* range ($\leq$2300) food availability is ranked first and women’s education second. For countries falling into the medium and high (>3,120) *DES* ranges, however, women’s education is ranked first and food availability last. The policy implications of these rankings will be drawn out more fully in Section 8.

For the basic determinants, national income appears to be a more potent force for reducing child malnutrition than is democracy. The full sample elasticity of GDP per capita, at –1.26, is much higher than that of *DEMOC*. The required increase in GDP to reduce the child malnutrition prevalence by one percentage point is $74. This is a very small proportion of the variable’s range, less than 1 percent. By contrast, a very large change in democracy would be required to bring about the same change, an increase in the index of 0.8 points (13 percent of its range). The stronger impact of national income than democracy holds even for the medium GDP segment (between $800 and $4,725). For the high GDP group (>$4,725), however, democracy prevails as the most potent basic determinant.

Differences across regions. Past studies suggest that there may be differences across the developing regions in the determinants of child malnutrition or in the magnitude of their effects, especially for South Asia (see Section 3 on past studies). For the underlying-determinants FE model, a Chow F-test of parameter stability across the regions does not reject the null hypothesis that all the coefficients are identical across regions. While some regional differences probably do exist, they are not strong enough to detect given the data in our sample. We thus assume that the underlying-determinant parameter estimates given in Table 8 columns (3) and (4) apply to all of the regions.

While from a structural standpoint the child malnutrition-DES relationship does not differ substantially across the regions, the regions do differ greatly in terms of the *levels* of their per capita DESs (Table 13, column 1). Because the strength of this determinant depends on its level, the regions thus differ greatly in the strength of impact of DES on child malnutrition. Table 13, column (2) reports estimates of the DES regression coefficients for each developing-country region.[28] Corresponding to their low per capita DESs over the study period, the effects for Sub-Saharan Africa and South Asia are the highest in magnitude, both at about -0.01. The other regions have substantially higher DES per capitas, and thus their coefficient estimates are much lower in magnitude.

For the basic-determinants FE model, the Chow F-test for parameter stability rejects the null hypothesis that all the coefficients are identical across regions. The result suggests that there are significant structural differences across the regions in the effects of national income and/or democracy and, in particular, that South Asia differs fundamentally from the others.

As for food availability, the effect of per capita national incomes on child malnutrition for any region depends on it level. Table 13 reports regional mean GDPs (column 3) and the estimated regional GDP regression coefficients (column 4). In South Asia and Sub-Saharan Africa, which had the lowest GDP per capitas over the study period, the effect of national income is relatively strong. It is much weaker for East Asia, NENA and LAC.

Note that the regression coefficients reported in Table 13 reflect the regions' average DES and GDP positions as they stood over 1970-95. In Section 8, regional differences are discussed in the context of the regions' current positions, which differ substantially from the 25-year study period.

[28] These coefficients are calculated as a weighted average of the segment parameter estimates, where the weights are the proportion of the sample data points of the region falling into each segment.

Our final clue as to whether there are substantial regional differences in the causes of child malnutrition lies in the magnitudes of the country fixed-effects terms included in the regression equations. These terms represent the effects of factors that do not change very much over time (over 13-year periods). A very clear result from the analysis is that the influence on child malnutrition of these unobserved factors is much stronger for South Asia than for the other regions. The mean of the fixed-effects coefficients in the underlying determinants model is 9.6; the mean for South Asia is far above that for the sample and the other regions, at 33.3.[29] The significance of this finding is clarified in Section 8 (Box 2).

Estimation Results for Dynamic Models

Tables 14 and 15 present the results of the dynamic model estimations for the basic and underlying determinants, respectively.

Consider first the OLS-estimated basic-determinant results (Table 14, column 1). Controlling for current levels of per capita GDP and democracy, child malnutrition in the previous period is estimated to have a highly statistically significant affect on current levels of child malnutrition. This result suggests a strong link between current and past levels of child malnutrition—whether that be through cumulative affects on children over time or intergenerational linkages. The OLS estimates for the underlying determinants (Table 15, column 1) also indicate a strong positive relationship between current and past child malnutrition. *SAFEW* is the only other variable whose parameter estimate is statistically significant.

In the country fixed-effects estimates for both basic- and underlying-determinant models, the coefficient on lagged *CHMAL* is not statistically significant. Note, however, that the t-statistics on the coefficients are fairly high. The FE estimations require three data points in time to be available for any country included: the current observation, the lagged observation, and a twice-lagged observation (as an instrumental variable). Thus the estimations were limited to 36 countries (54 data points). Only as more data become available will it be possible to determine in a robust manner whether the estimates are statistically significant.

Overall, this analysis indicates—but is not able to give strong evidence in support of—the possibility that child malnutrition may have substantial "feedback" effects. The

[29] The average fixed-effects coefficients for the other regions are Sub-Saharan Africa, 6.3; East Asia, 19.3; NENA, 2; and LAC, 5.7 percentage points.

coefficient estimates on lagged child malnutrition reported in Tables 14 and 15 range from a low of 0.28 to a high of 0.838. If these estimates can be verified, they indicate that a one percentage-point increase in the prevalence of child malnutrition today contributes to between a 0.3 and 0.8 percentage-point increase in child malnutrition in the future regardless of the status of health environments, women's education, women's status, food availability, national income, and democracy.

6. HOW HAS CHILD MALNUTRITION BEEN REDUCED IN THE PAST?: A RETROSPECTIVE

The approximate reductions in the prevalence of child malnutrition that have taken place between 1970 and 1995 for the developing countries as a group and for individual regions are summarized in Table 1. How have these reductions been brought about?

To answer this question, we start with the fixed-effects parameter estimates of Table 8 (columns 3 and 4) to formulate a predicting equation for the change in child malnutrition prevalence over 1970-95. Using the underlying-determinants model as an example, the base predicting equation is

$$\begin{aligned} C\hat{M}_t = 140 &- .076 * SAFEW_t - .220 * FEMSED_t - 71.8 * LFEXPRAT_t \\ &- .017 * DES1_t - .002 * DES2_t + 0.0 * DES3_t + \hat{\mu}, \end{aligned}$$

where $\hat{\mu}$ is the fixed-effect term. This term is wiped out using a first-difference transformation as follows:

$$\begin{aligned} \Delta C\hat{M} = C\hat{M}_{1995} - C\hat{M}_{1970} = &.076 * \Delta SAFEW - .220 * \Delta FEMSED - 71.8 * \Delta LFEXPRAT \\ &- .017 * \Delta DES1 - .002 * \Delta DES2 + 0.0 * \Delta DES3 . \end{aligned}$$

Each determinant's absolute and percentage contribution to the total change are then calculated.[30] The absolute and percentage contributions, respectively, of *SAFEW*, for example, are

[30] 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 (e.g., lung cancer) from exposure to risk factors (e.g., 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 and Sempos 1989).

$$-.076 * \Delta SAFEW \qquad \frac{-.076 \Delta SAFEW * 100}{\Delta CM}.$$

For information on how much each determinant has actually changed over the period for our sample, we expand our data set to include all available data on the basic—and underlying—determinant variables at six points in time: 1970, 1975, 1980, 1985, 1990, and 1995. The mean levels of the determinants for each of these years as well as their total change over the study period are given in Table 16. Appendix Tables A3 through A7 contain the information by region.

The estimated contribution of each underlying determinant to reductions in the developing-country prevalence of child malnutrition from 1970 to 1995 is given in the upper panel of Table 17. The total contribution of the underlying determinants for our sample is a reduction of 15.9 percentage points (Row 4). Given a 15.5 percentage-point reduction for all developing countries over the study period (Table 1), the estimated change based on these contributions thus likely accounts for a large portion of the total.

Figure 9 summarizes the estimated percent contribution of each underlying determinant to the reduction in the child malnutrition prevalence. The change in each over the period on an equivalent (100 percent) scale is also presented to aid in interpretation (Figure 9a). Improvements in female education have contributed by far the most, almost 43 percent. This contribution is the combined result of both the strong effect of the determinant and a fairly big increase in it over the period. The contribution of improvements in health environments has been substantial: almost 20 percent. Improvements in food availability have contributed to around a quarter of the reduction in the child malnutrition prevalence due both to a strong effect of this variable and fairly substantial increases, from 2,092 kilocalories per capita in 1970 to 2,559 in 1995. The lowest contribution (12 percent) has come from improvements in women's status as gauged by the female-to-male life expectancy. While this factor has a strong impact on child malnutrition, it has improved very little (Figure 9a). Together, the contributions of women's education and relative status have contributed to over half of the 1970-95 reduction in the developing-country prevalence. We can thus surmise that much of the reduction was due to improvements in maternal and child care, confirming its critical role in the etiology of child nutrition. Some of the effect may also be working through improved household food security.

Figure 10 traces out the contributions of the underlying-determinant variables to changes in child malnutrition prevalences for five-year intervals over the study period, starting with 1970-75 and ending with 1990-95. The change in the malnutrition prevalence over the intervals, in percentage points, is marked on the vertical axis. When there has been a *reduction* in child malnutrition associated with *increases* in a determinant, the bar falls below zero. A bar value above zero indicates that there has been an increase in child malnutrition due to a reduction in the level of a variable.

There are several points to note from the figure.

- There has been a fairly steady decline in the developing-country child malnutrition prevalence of about 3.2 percentage points every five years since the early 1970s. The largest reduction, 4 percentage points, came in the 1975-80 period. Since then they have been smaller;
- The contribution of improvements in health environments has declined over the 25-year period; in the early 1990s it made very little contribution;
- Women's education made its greatest contribution in the early 1970s and early 1990s. Its contribution dropped dramatically between 1970 and 1980; since then it has gradually increased. It contributed 84 percent of the total 2.7 percentage point reduction in the underweight prevalence in the early 1990s;
- Corresponding to the world food crisis of the 1970s, food availability declined over 1970-75. Accordingly, this factor lead to a slight *increase* in child malnutrition. As the green revolution picked up, the developing countries saw substantial increases in their food supplies. The contribution of food availability to declines in malnutrition were steady and substantial in the late 1970s and early 1980s. Despite continued increases in food availability in the late 1980s and early 1990s (see Table 16), their contribution to reductions in child malnutrition has leveled off due to a decline in strength of their impact as they have increased.
- As improvements in women's status have fluctuated over the 25-year period, so too has their contribution to malnutrition reductions. The greatest contribution was made in the early 1980s; since the late 1980s, it has declined considerably.

The bottom panel of Table 17 gives the contribution of the basic determinants. Democracy has actually deteriorated slightly. Despite its potential positive influence, its contribution has thus been to increase child malnutrition. Improvements in per capita national income, however, have been quite large. For the full sample of countries, per capita GDP rose from $1,011 in 1970 to $2,121 in 1995, more than doubling. This large increase, in combination with the strong influence of the variable, has facilitated an estimated 7.4 percentage-point reduction in child malnutrition. The influence of national incomes in reducing malnutrition developing-world-wide over the 25-year period since 1970 has thus been quite strong. Figure 11 breaks the basic determinants' contributions down for five-year periods. While democracy made positive contributions in the 1970s, since then its decline has put a drag on child nutrition improvements. Aside from the early 1980s, the contribution of national income has been steadily increasing since the 1970s. Its greatest contribution came most recently: in the 1990-95 period alone, it contributed to a 3 percentage-point decline in the prevalence.

Since there are fundamental differences across the regions in the strength of impact of the basic determinants, precise region-specific estimates of their contributions cannot be undertaken (see Section 5.2.1.4). We can infer, however, that the contribution of national income has been positive for all regions except Sub-Saharan Africa (where it declined). The contribution of democracy has been positive for Sub-Saharan Africa, NENA, and LAC, but due to deteriorations has been negative in South and East Asia. The regions have had equally differing experiences with respect to the contributions of the underlying determinants. These contributions can be quantified using the full-sample coefficient estimates of Table 8, column (3).

The overall reduction in the prevalence of child malnutrition in **South Asia** for the 25-year period is estimated to be 16.5 percentage points. As illustrated in Figure 12a, the greatest contributions to this reduction have come from increased education of women and improvements in health environments, at about 28 percent each. Improvements in women's relative status have accounted for about a quarter of the reduction, and improvements in food availability about 20 percent. Figure 12b indicates that there has been substantial fluctuation in the factors' relative contributions over the study period. In the early 1970s, reductions in child malnutrition due to improvements in health environments, women's education, and women's relative status were completely undermined by reductions in food supplies. As a result, no progress was made. By the late 1970s, food availability had improved and continued on to contribute substantially to the reductions in child malnutrition of the 1980s and early 1990s. The 1980s saw a precipitous decline in the region's prevalence (over 11 percentage points) due to improvements in all of the factors. However, in the 1990-95 period, it appears that the pace of improvement has been severely curtailed by slower growth in health environment improvements and food availabilities.[31] While women in the region continue to have the lowest status compared to men of all developing-country regions (the 1995 female-to-male life expectancy ratio was 1.02), small improvements have made a steady contribution over the 25 years.

The total reduction in **Sub-Saharan Africa's** child malnutrition rate over the study period is estimated to be only 4.2 percentage points. This overall net reduction masks the negative effect that deteriorations in women's relative status have posed over the study period. Figure 13a gives the percent contributions of the remaining factors to reductions in the region's child malnutrition prevalence. The large majority was brought about by increases in women's education, followed by improvements in health environments. A very small contribution was made by improvements in food availability. Figure 13b gives a fuller picture of the role the underlying determinants have played. Improvements in health environments have made their greatest contribution since 1985. Increased education of women made strong contributions in all periods except for the late 1980s, when enrollments actually declined. Women's relative status has continually declined in the region since the 1970s, most precipitously after 1985. Its contribution has thus been to *worsen* the region's child malnutrition prevalence throughout the study period. Changes in food availabilities have played a large role overall. However, the role was not always positive. Substantial improvements in the late 1980s and early 1990s were outweighed by deteriorations, for the most part, over the 1970-1985 period.

East Asia has seen the fastest decline in child malnutrition prevalence over the study period, of 20 percentage points. The greatest contribution to this decline came from increases in women's education, followed by improvements in food availability and health environments (Figure 14a). The early 1970s witnessed a very large reduction in child malnutrition, of over 6 percentage points (Figure 14b), most of which was due to increases in women's education. Progress since this period was not as great, but continued steadily. The contributions of health environment and women's relative status improvements declined over the period, and were minimal by the 1990s. Improvements in food availability have taken place at a relatively fast pace in East Asia, rising from

[31] Their declining contribution is partially due to their declining impact as food supplies increased over the period.

Box 1: Why has child malnutrition been rising in Sub-Saharan Africa?

Sub-Saharan Africa is the only region in which the prevalence of child malnutrition has been increasing. From 1985-95 it increased from 25.8 percent to 31.1 percent (Table 1). Of the four underlying determinants, only one of them**—women's relative status**, as proxied by the female-to-male life expectancy ratio—was moving in the wrong direction over the period (Box Table 1). The region's **national income** also declined significantly—per capita GDP fell by $52, which is reflected in a slight increase in its **poverty** rate and is responsible for the slow progress in all of the underlying determinants. We can thus surmise that it is deteriorations in women's relative status, per capita national income, and household incomes that partially explain the deterioration in child nutrition in the region. Other (related) factors may be (1) deteriorations in the capacity and outreach of government services under the impact of **debt and structural adjustment**; (2) the rising incidence of **HIV/AIDS** (Ramalingaswami, Johnsson, and Rohde 1996); and (3) **conflict** (Messer et al. 1998). The decline in women's life expectancy relative to men is puzzling. It may be because women are more vulnerable to HIV/AIDS in the region than men (Brown 1996), itself a reflection of women's lower status.

1,998 kilocalories per capita in 1970 to 2,720 in 1995. Overall they have contributed to about a 6 percentage-point reduction in the child malnutrition prevalence. The majority of the contribution took place in the 1970 to 1985 period. As per capita dietary energy supplies have increased beyond 2,722 kilocalories, further increases have had less impact. Thus, in the 1985 to 1995 period, even though food supplies continued to increase at a fairly fast pace, they made little contribution to reductions in child malnutrition.

Almost all of the 12 percent-point reduction in the child malnutrition prevalence of the **Near East and North Africa** region has come from increases in women's education (Figures 15a and 15b). Health environment improvements have fluctuated with deteriorations—the net result being a very small contribution of 3.6 percent. Women's relative status deteriorated in most periods, muting child nutrition improvements. Improvements in food availabilities have contributed to 19 percent of the reduction in child malnutrition. As for East Asia, food availabilities have improved in all periods, but their impact has declined with great increases. By 1995, they had reached 3,172 kilocalories, a point at which they have no or minimal impact.

The **Latin America and Caribbean** region experienced an estimated 11 percentage-point reduction in child malnutrition over the study period, most of which took place from 1970-80. Since then, reductions in child malnutrition have continued at a much slower pace (Figure 16b). As for the other regions, the greatest contribution (62 percent) came from expansions in female education (Figure 16a). The contribution of improvements in health environments has steadily declined. Strong improvements in women's relative status in the 1970s were followed by very small improvements in the 1980s. By the early 1990s, there was a slight decline, muting the overall reduction in malnutrition of the period. Food availabilities improved in the 1970s, but declined slightly in the early 1980s. Their contribution has been minimal since the early 1980s.

7. PROJECTIONS OF CHILD MALNUTRITION IN THE YEAR 2020

Up to this point, we have focused on the period 1970-1995. Looking toward the next 25 years, by how much is the developing-country prevalence of child malnutrition likely to decline by the year 2020? How fast is the decline likely to take place? Which regions are likely to experience the greatest improvements? Given population growth, are the *numbers* of children who are malnourished likely to increase or decrease? Future prevalences of child malnutrition are obviously dependent on levels of effort exerted to reduce them. To answer these questions, we use the estimation results of Table 8, columns (3) and (4), and consider three scenarios based on the projected evolution of the underlying determinants of child malnutrition over the period 1995-2020. These are (1) a status quo, or "do nothing different" scenario, (2) a pessimistic scenario, and (3) an optimistic scenario.

For the evolution of safe water access, female secondary enrollments, and the female-to-male life expectancy ratio under the alternative scenarios, we rely on various assumptions regarding their average annual increase over 1985-95. For per capita dietary energy supplies, we rely on projections generated by IFPRI's IMPACT model (Rosegrant, Agcaoili-Sombilla, and Perez 1995).[32] These projections are based on assessments of future developments in the world food situation (including changing prices of food and changes in agricultural productivity) and various assumptions about future agricultural research investments, population growth,[33] and growth in nonagricultural incomes. The levels of each explanatory variable in 1995 and under the alternative scenarios are given in Table 18, rows (3)-(6).

The assumptions underlying each scenario are as follows.

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[32] The IMPACT model is the International Model for Policy Analysis of Agricultural Commodities and Trade. Developed at IFPRI, it is made up of a set of 35 country or regional models that determine supply, demand, and prices for 17 agricultural commodities.

[33] United Nations 1992 medium population growth rates are employed as the basis for population projections.

STATUS QUO SCENARIO

In the status quo scenario, safe water access, female secondary enrollments, and the female-to-male life expectancy ratio improve at the same rates they improved over 1985–95 (Table 18, column 2). At these rates, 94.3 percent of the developing-country population would have access to safe water by the year 2020. Female secondary enrollment would increase from 47 percent to 87 percent in 2020. The female-to-male life expectancy ratio would rise to 1.066. Per capita dietary energy supplies rise from 2,595 to 2,821 kilocalories corresponding to current trends in agricultural research investments, population growth, and nonagricultural income growth.

PESSIMISTIC SCENARIO

Under the pessimistic scenario, the rate of improvement in the nonfood underlying determinants is assumed to decline by 25 percent. Under this circumstance, access to safe water rises to only 88.3 percent, female secondary rises to 77 percent, and the female-to-male life expectancy ratio to 1.061. Per capita dietary energy supplies are assumed to rise to 2,662 kilocalories. This projection is based on a "low-investment/slow growth" scenario in which international donors eliminate public investment in national agricultural research systems and extension services in developing countries and phase out direct core funding of international agricultural research centers. In addition, nonagricultural income growth is reduced by 25 percent from 1990 levels (Rosegrant, Agcaoili-Sombilla, and Perez 1995).

OPTIMISTIC SCENARIO

In the optimistic scenario, the rate of improvement in safe water access is enhanced by 25 percent, leading to universal access by the year 2020. Female secondary enrollments climb to more than double the 1995 prevalence, reaching 97 percent. The female-to-male life expectancy ratio rises to 1.07. Corresponding to annual increases of US$750 million in funding for national and international agricultural research and a 25 percent increase in nonagricultural income growth, per capita dietary energy supplies increase to 2,978 kilocalories (Rosegrant, Agcaoili-Sombilla, and Perez's high investment/rapid growth scenario).

The base predicting equation is

$$\Delta\hat{CM} = \hat{CM}_{2020} - CM_{1995} \;=\; .076*\Delta SAFEW - .220*\Delta FEMSED - 71.8*\Delta LFEXPRAT$$
$$-\; .017*\Delta DES1 - .002*\Delta DES2 + 0.0*\Delta DES3\,.$$

We undertake the predictions using both full-sample and regional predictions of the underlying-determinant explanatory variables rather than predictions for each country individually. The predicted 2020 child malnutrition prevalence is recovered as

$$\hat{CM}_{2020} \;=\; \Delta\hat{CM} \;+\; CM_{1995}.$$

Table 18, rows (1) and (2), reports the resulting predicted prevalences and numbers of malnourished children in 2020. Figure 17 maps out the projections under each scenario for 1970, 1995, 2010, and 2020, showing their predicted evolution over the 50-year period. Under the pessimistic scenario, the percent of developing-country children expected to be malnourished in 2020 would fall to 21.8. The numbers would fall from a 1995 level of 167.1 million to 155 million, a reduction of only 12.3 million children. The status quo scenario is projected to lead to a 12.6 percentage point reduction in the prevalence (which is close to the reduction over the 25 years from 1970-1995). The numbers of children malnourished would decrease by 26.8 million. Under the optimistic scenario of more rapid improvement in the determinants, the child malnutrition prevalence would remain fairly high, but fall to 15.1 percent. Even under this most positive of scenarios, 128 million children would remain malnourished, a reduction of only 39.5 million children from present levels.

The projections for the developing countries as a whole mask wide variation across the regions. Table 19 reports regional projections; they are illustrated in Figures 18 (for prevalence) and 19 (for numbers). There are several points to note.

- Under all scenarios **South Asia** will remain the region with the highest prevalence and numbers of malnourished children. However, both will fall rapidly over the 1995-2020 period. In the status quo or most likely scenario, the prevalence will fall from 49.3 percent to 37.4 percent. Despite a slight increase in the population of children under five (from 174 to 176 million), the numbers of malnourished children will fall from 86 million to 66 million, a 23 percent decline.

- Little progress in reducing child malnutrition will be made in **Sub-Saharan Africa**. Under the pessimistic scenario, the prevalence is predicted to *increase*, from a 1995 rate of 31.1 percent to 32.4 percent in 2020. Even under the optimistic scenario, the prevalence would drop only by 5.4 percentage points. Given slow rates of decrease in the prevalence and very large expected increases in the numbers of children under five (101 to 169 million), under all scenarios the numbers of children are expected to increase in the region. They rise to as high as 55 million under the pessimistic scenario, a number not far below those for South Asia.
- The prevalence and numbers of malnourished children are expected to decline the fastest in the **East Asia** region. Under all scenarios, the prevalence is nearly cut in half, falling to about 12 percent of the population. No increase is expected in the number of children under five over the period. The numbers of malnourished children thus fall precipitously from 38.2 to around 21 million.
- In the **Near East and North Africa** region, malnutrition will fall to very low levels, except under the pessimistic scenario, in which almost 5 million children under five will remain malnourished.
- Malnutrition will practically be eliminated in **Latin America and Caribbean** (although there will likely remain some countries within the region for which rates remain high).

Corresponding to the above predicted trends, the regional configuration of the locations of malnourished children in the developing world is expected to change considerably by the year 2020 (Figure 20). Under the status quo scenario, South Asia's share is predicted to remain high, but to fall from 51 percent to 47 percent. Sub-Saharan Africa's is expected to rise from 19 percent in 1995 to almost 35 percent by the year 2020.

8. PRIORITIES FOR THE FUTURE

Sections 5 and 6 of this report examined the past record of reductions in child malnutrition and attempted to isolate the contributions of four underlying and two basic determinants. Section 7 then developed three scenarios for child malnutrition in the year 2020 based on past trends in these determinants. The scenarios are essentially the answer to the question, "If we continue as in the past (or continue doing a little more or a little less), what will the future look like?" Even under the most optimistic of the scenarios, the developing-country prevalence of child malnutrition is expected to be 15 percent in 2020. One hundred and twenty-eight million children would still be malnourished. But the future doesn't have to look like the past.

This section asks: "What combinations of actions would lead to the greatest reductions in child malnutrition in the developing countries by 2020, and how difficult would they be to put into effect?" In answering this question, it is important to keep three things in mind. First, as the conceptual framework of this paper lays out and the analysis has confirmed, all three underlying determinants—food security, mother and child care, and a healthy environment—are necessary for a child to achieve adequate nutritional status. Thus strategies for reducing child malnutrition should address all of them. The issue addressed here is the *relative* emphasis that should be placed on the various contributing factors. Second, we have found both underlying and basic determinants to have strong effects on child malnutrition, with the former being dependent on the latter. The question we ask here is not which set of determinants should be prioritized: *both* underlying and basic determinants should be the focus of future efforts to reduce child malnutrition. Finally, actions associated with the determinants considered in this paper should be seen as complementary to more direct measures that have been the traditional focus of nutrition interventions, such as breast-feeding promotion, nutrition education, supplementary feeding, and food fortification (see Gillespie et al. 1996).

THE RELATIVE IMPORTANCE OF NATIONAL FOOD AVAILABILITY, WOMEN'S EDUCATION, WOMEN'S RELATIVE STATUS AND HEALTH ENVIRONMENT IMPROVEMENTS TO FUTURE REDUCTIONS IN CHILD MALNUTRITION

As seen below, the strength of the effect of per capita dietary energy supplies (DES) on child malnutrition for any population depends strongly on the level currently reached. The *relative* strengths of the underlying determinants thus also depends on the current DES level. Using the estimates of Table 8, column (3), Table 20 classifies the developing countries into three DES groups, a "high impact" group, whose DES's are below 2,300 kilocalories, a "medium impact" group, whose DES's are between 2,300 and 3,120, and a "low impact" group, with DES's above 3,120 kilocalories. Most of the countries in South Asia and Sub-Saharan Africa fall into the high impact group. Some, however, among which are countries with very high prevalences of child malnutrition such as Pakistan, India, Mauritania, and Nigeria, fall into the medium impact group. Most countries in East Asia and Latin America and the Caribbean (LAC) fall into the medium impact group. However, some countries in these regions with very low DESs—Cambodia, Mongolia, Laos, Haiti, Bolivia, Peru, and Guatemala—fall into the high impact group. South Korea, Mexico, and Barbados, as well as a large number of Near East and North Africa (NENA) countries fall into the low impact group, in which further increases in food availabilities are unlikely to lead to improvements in children's nutritional status.

The country classification given in Table 20 helps to compare the strengths and potential impacts of the underlying determinants for each developing region. The upper panel of Table 21 gives the comparison. In column (2), calculations of the absolute increase in each determinant needed to bring about a reduction in the child malnutrition rate of one percentage point by region in 1995 are presented. Hence, for example, in South Asia, an increase in the rate of access to safe water of 13.1 percentage points would have the same effect on child malnutrition rates as would an increase in per capita DES of 94 kilocalories. But, as discussed earlier in Section 5, the different units in which the determinants are measured make this column difficult to interpret. We thus standardize the absolute increases in Table 21, column (2) by the range of the determinants observed in developing countries to gauge how realistic they are (column 3).

In South Asia and Sub-Saharan Africa, food availability emerges as the determinant that needs to change the least—relative to its existing range—to bring about a one percentage-point drop in child malnutrition rates. It is thus the most potent force in reducing child malnutrition in these regions. Following close is female secondary enrollments in both regions. In the remaining three regions, female secondary enrollments are by far the most potent force for reducing child malnutrition. In all regions except NENA, access to safe water is the determinant that needs to change the most—relative to its range—to bring about a 1 percentage-point reduction in child malnutrition.

While the numbers in column (3) provide us with a sense of how large a change is required in each determinant to bring about the same reduction in child malnutrition, they say nothing about the distance of the determinants from their desirable levels and hence the scope for reducing child malnutrition over the medium to long-run. The percent that each determinant is below its desirable level (in scale-neutral terms) is given in column (4). The desired levels of safe water access and female secondary enrollments are assumed to be 100 percent. The desired level of the female-to-male life expectancy ratio is set at 1.01; that of per capita dietary energy supplies is set at 3,100.[34] Column (5) gives the estimated reduction in the child malnutrition prevalence if each determinant were raised to its desirable level.

In all regions, increasing female secondary education to the desirable level has the largest medium-term to long-term potential to reduce child malnutrition. Food availability is second in Sub-Saharan Africa. Women's relative status is second in South Asia, East Asia, and NENA, and access to safe water is second in the LAC region.

To identify policy priorities for future reductions in child malnutrition for each region, we rank the determinants in terms of (1) the size of the change required in them to bring about a one percentage-point reduction in child malnutrition as a percentage of the determinants' ranges (based on Table 21, column 3); and (2) their scope for reducing it in the medium-to-to long term (based on column 5). Combining these two sets of ranks, our best estimates (in the absence of cost data—discussed below) of future policy priorities for addressing the underlying determinants of child malnutrition in each developing region are summarized in Table 22.

In South Asia and Sub-Saharan Africa, the top priorities are food availability and female education. In both regions, food availability improvements have the strongest effect, but women's education has a strong effect *and* would make the biggest difference if increased to its desirable level. In East Asia, NENA, and LAC, women's education is the top priority, both from the standpoint of strength of impact and scope for reducing child malnutrition. In East Asia, food availability and women's relative status should also be prioritized. In NENA, women's relative status is in second priority. In LAC, women's relative status and health environment improvements tie for second priority.

Health environment improvements, in a *relative* sense, appear to be a weak force for reducing child malnutrition. Its low ranking is partially because there has already

[34] The desired level of the female-to-male life expectancy ratio is determined as the average of the top 20 percent of the data points in our panel data set, excluding the maximum value (1.15) of El Salvador in 1988, which is an extreme value compared to the other high ratios. There is no widely-accepted "desirable" level of per capita dietary energy supplies from the stand point of nutritional health. Countries with very high levels also have high levels of obesity, an undesirable trait. This is the case for many high-income countries, for example, those of Western Europe, which have an average (1995) DES of 3,360 (FAO 1998). We have also estimated that somewhere near a DES of 3,120 kilocalories, increases in dietary energy supplies no longer serve to reduce child malnutrition levels. Alexandratos (1995) cites the general case that 10 percent of a country's population will be undernourished (or food insecure) at DES levels of 2,700 kilocalories. On the other hand, FAO (1996) claims that at a level of about 2,770, only 2.5 percent of the population will be undernourished. We chose an intermediate level between 2,770 and 3,360 (of Western Europe) that is close to 3,120 as the desired target: 3,100 kilocalories.

been substantial progress made in this area compared to the others (Table 21, column 4). In an absolute sense, it still makes quite a big difference, however. We estimate that if universal access to a proper health environment (proxied by safe water) were achieved, the prevalence of child malnutrition would fall by 2.3 percentage points. The numbers of malnourished children would fall by 11.9 million. Its potential for reducing child malnutrition is the greatest in Sub-Saharan Africa.

THE RELATIVE IMPORTANCE OF NATIONAL INCOME AND DEMOCRACY

We have seen that democracy is important in facilitating health environment improvements and increases in food availability. Per capita national income is important in maintaining and improving investments in health environment improvements, female education, women's relative status and food availability, both from the viewpoint of public investments and (through its association with household incomes) investments at the household level (Table 9). As for DES, the strength of its effect depends on its current level. Strong (but inestimable) regional differences in the effects of the basic determinants have been detected. We thus limit our discussion of their relative strengths to the developing countries as a group.

At this point in history, it appears that raising national incomes would have a stronger effect than enhancing democracy. We estimate that it would take an increase in the developing country per capita GDP of $202 to reduce the child malnutrition prevalence by one percentage point, which is 9.7 percent of its range (Table 21, lower panel). By contrast, it would take almost an 0.8 point rise in the democracy index to bring about the same reduction (11.5 percent of its range). The developing-world per capita GDP is currently far below any desirable number. Past a level of about $4,750, the factor loses its force in reducing child malnutrition. Even bringing the developing-country GDP up to this moderate level would have quite a large impact on child malnutrition: the prevalence would fall by a predicted 18.5 percentage points, the numbers by almost 100 million. The regions that have the longest way to go to reach the $4,750 mark (and thus the most to gain from doing so) are Sub-Saharan Africa, South Asia, and East Asia. Latin America and the Caribbean, as a region, has already surpassed the mark (see Tables A3-A7).

While, relatively speaking, democracy is not a very strong force in reducing child malnutrition in the developing countries, in an absolute sense, improving it would make a big difference. If the democracy index were raised to its desired level (of 7), we estimate that the prevalence of child malnutrition in the developing countries would fall by 5.5 percentage points. The numbers of children who are malnourished would be reduced by

29.4 million. The regions that have the longest way to go to reach a desirable level of democracy are East Asia, NENA, and Sub-Saharan Africa.

The reader should bear in mind that improvements in national income and democracy only lead to reductions in child malnutrition *if* they are directed to improvements in the underlying determinants. Given enhanced political will and education, it is possible that they can be even more effectively directed towards them in the future than they have in the past. Our analysis gives governments an idea of where to best direct increased national incomes in the interests of children's nutrition. It also suggests target areas in which political will and commitment among democratic governments can be instilled.

A NOTE ON COST-EFFECTIVENESS

On a final note, for a full assessment of priorities for the future, we would ideally want to take into account the costs of improving the alternative determinants. While the same reduction in child malnutrition could be brought about by a 13.1 percentage-point increase in access to safe water as a 4.6 percentage-point increase in female secondary enrollments, it is unlikely that these increases would cost the same. Their costs are likely to differ by region as well. Unfortunately, good quality comparative information on cost-effectiveness of these different policies is lacking. One can still get a sense of how different the relative costs have to be before the conclusions reached on priorities are altered. For example, if it cost more than 2.8 times as much to increase female secondary enrollment by one percent compared to the costs of increasing access to safe water by one percent, then the latter will be the more cost-effective investment in reducing malnutrition. If the ratio is below 2.8, then female secondary education becomes more cost-effective. Better information on cost-effectiveness should be the focus of future research on policies to improve child nutritional status.

9. SUMMARY AND CONCLUSIONS

Thirty percent—167 million—of all developing-country children under five are currently malnourished. The overall objective of this study was to use historical cross-country data to improve our understanding of the relative importance of the various causes of this malnutrition for the developing countries as a whole and by region. In this way, we hoped to contribute to the debate on how to make the best use of available

Box 2: The (South) Asian Enigma

South Asia's child malnutrition prevalence is 50 percent. Sub-Saharan Africa's is 31 percent. Why is South Asia's so much higher? The great difference has recently been called an "enigma" because South Asia as a region is doing so much better than Sub-Saharan Africa for most of the determinants of child malnutrition (see Box Table 2) (Ramalingaswami, Johnsson, and Rohde 1996). There are three possible sources of the differences.

The first is that the determinants of child malnutrition are different or have different strengths of impact in the regions. If one were more important in South Asia, and South Asia is not doing very well in the area—regardless of how well Sub-Saharan Africa is doing, then that determinant would be a clue to the enigma. This study finds no major differences between the regions in terms of the importance of the underlying determinants of child malnutrition—health environment, women's education and relative status, and national food availability—as causal factors. For the basic determinants, however, we find that democracy and national income are more important in South Asia than the other regions, including Sub-Saharan Africa. South Asia is doing fairly well in the area of democracy. Even though it is doing better than Sub-Saharan Africa in the area of **national income**, it is still doing very poorly. Since this factor is more important in determining child malnutrition in South Asia than in Sub-Saharan Africa, it may be one reason why South Asia is doing worse. Since national income is so strongly linked with **poverty**, and South Asia is also doing poorly (even worse than Sub-Saharan Africa) in this area, it may also be a clue.

The second possible source of the difference in the regions' child malnutrition rates is that, of the determinants we have considered that are equally important in the regions, South Asia is doing worse than Sub-Saharan Africa. Box Table 2 shows that South Asia is doing better than Sub-Saharan Africa in all these areas except **women's relative status**. We can thus surmise that, among the observed determinants in child malnutrition that we have considered in this study—those that change over time, women's status is a primary reason for the region's differing prevalences.

The final source of the difference in the regions' child malnutrition rates lies in the **"black box" of unobserved, time-invariant country-specific factors**. Because our data set covers more than one point in time for each country, we have been able to estimate the effects on child malnutrition of these factors. They are found to raise South Asia's child malnutrition prevalence above Sub-Saharan Africa's substantially. To illustrate their importance in the regional differences, Box Figure 1 shows how much child malnutrition would remain even if all of the underlying determinants were raised to their desirable levels. In South Asia, a 23.8 percent prevalence would remain, but only 0.5 percent in Sub-Saharan Africa. These deeply-entrenched factors somehow specific to South Asian countries, then, are also key to solving the Asian Enigma. In the long run, if child malnutrition is to be overcome in the region, attention must be paid to opening the black box to find out what they are and implementing policies to address them. Some possibilities are a monsoon climate (FAO 1996), including recurrent flooding in some countries, overcrowding due to high population density, and cultural beliefs and traditions that hinder optimal breast-feeding and timing of the introduction of complementary foods (Ramalingaswami et al. 1996).

resources to reduce malnutrition in developing countries now and in the coming years to 2020.

The conclusions of the study are based on estimations undertaken with careful consideration to data quality and statistical soundness. The study is guided by a well-accepted, comprehensive conceptual framework. It employs household survey-based nationally-representative underweight prevalence data that have been subjected to strict quality control standards. It employs an estimation methodology that yields unbiased parameter estimates. Specification test results indicate that the models estimated are a reasonably good representation of the quantitative relationships between child malnutrition and its determinants and that we have done the best we can, given available data, to identify a causal relationship between them. We thus believe that we have succeeded in our goal of making maximum use of the available data.

The estimation results in Section 5 show that all four of our variables representing the underlying determinants of child malnutrition—health environments, women's education, women's relative status, national food availability—have significant impacts on child malnutrition. The basic determinants—national income and democracy—have strong impacts through facilitating investment in the underlying determinants.

The study has found weak evidence of a feed-back effect of child malnutrition, i.e., that child malnutrition today, regardless of future levels of its determinants, contributes to greater levels of child malnutrition in the future. The existence of this linkage suggests that reducing child malnutrition at a fast pace today should reduce child malnutrition in the future at an even faster pace.

Section 6 presented estimations of the contribution each determinant made to the 15.5 percentage-point reduction in the prevalence of child malnutrition from 1970 to 1995. Among the underlying determinants, increases in women's education have made the greatest contribution, being responsible for 44 percent of the total reduction. Improvements in food availability contributed to 26 percent of the reduction, health environment improvements to 19 percent. Because there has been little improvement in women's relative status, its contribution—while still substantial—was the lowest (12 percent). In South Asia, in addition to women's education, particularly large contributions were made by improvements in women's relative status and health environments. While South Asian countries' per capita food availabilities deteriorated during the world food crisis of the early 1970s, improvements in the 1980s made a large contribution. In Sub-Saharan Africa, reductions in child malnutrition have taken place largely through increases in women's education and health environment improvements. Per capita food availability made very little contribution overall, although its positive impact on child nutrition in the last 10 years has demonstrated its future potential. Declines in women's relative status in the region have muted the positive impacts of the other determinants. In East Asia and the Near East and North Africa (NENA), increases in women's education and food availability have made the greatest contributions. In the Latin America and Caribbean (LAC) region, women's education has been a major contributor throughout the 25 years. The other determinants have made little contribution, especially in recent years.

In terms of the basic determinants, improvements in per capita national income have made a substantial contribution, an estimated 7.4 percentage-point reduction in the developing-country prevalence of child malnutrition. The contribution was positive for all regions except Sub-Saharan Africa. While democracy has a potentially large contribution to make, because little progress has been made in this area, its overall contribution has been minimal. Deteriorations in democracy have had a negative impact on child malnutrition in South Asia and East Asia.

The analysis in Section 7 projects the prevalence and numbers of malnourished children in the year 2020 under three scenarios for growth in the four underlying determinants. The status quo scenario assumes that the nonfood determinants increase at the rate they did over the 1985-95 period. For food availability, we use IFPRI IMPACT model projections (Rosegrant, Agcaoili-Sombilla, and Perez 1995). The pessimistic scenario assumes a 25 percent cut in the rate of change of the nonfood determinants plus the low investment IMPACT model projection for food availability. The optimistic scenario assumes a 25 percent increase in the rate of change of the nonfood determinants plus the high investment IMPACT model projection for food availability. Under the status quo scenario, 18 percent of developing-country children under five are projected to be malnourished in 2020. The prevalence rises to 22 percent under the pessimistic scenario and falls to 15 percent under the optimistic scenario. The payoffs to the optimistic scenario can be best realized in Sub-Saharan Africa and South Asia. What is particularly striking is that even under an optimistic scenario, the absolute numbers of malnourished children in Sub-Saharan Africa will be higher in 2020 than they are in 1995. Based on the status quo projections, we predict a sharp regional shift in the location of child malnutrition: South Asia's share will fall from 51 percent in 1995 to 47 percent in 2020, but Sub-Saharan Africa's share will increase from 19 percent in 1995 to near 35 percent in 2020.

Section 8 assesses the relative effectiveness of the four underlying determinants in terms of their potential for generating future reductions in child malnutrition. This exercise is undertaken in the absence of crucial cost-side information. The data indicate that improvements in per capita food availability and in women's education offer the best hope for future reductions in child malnutrition in Sub-Saharan Africa and South Asia. In East Asia, NENA, and LAC, the first priority is women's education. For East Asia, the second priorities are food availability and women's relative status. In NENA, the second priority is women's relative status. In LAC, they are women's relative status and health environment improvements.[35] Actions associated with these priorities should be seen as complementary to more direct measures that have been the traditional focus of nutrition interventions, such as breast-feeding promotion and food fortification.

The study contributes to the resolution of five important debates currently underway in development policy and research circles. First, why has child malnutrition been rising in Sub-Saharan Africa? Here, all we can say is that some of the increase is due to the declining relative status of women and deteriorations in per capita national incomes (and thus rising poverty). Debt and structural adjustment, increasing conflict levels, and the rise of HIV/AIDS may also be responsible, and this should be the subject of future research.

Second, why are child malnutrition rates in South Asia so much higher than in Sub-Saharan Africa? This study identifies two key variables at the source of the "Asian enigma": women's relative status (which is much worse in South Asia) and national income (very low in South Asia yet a particularly important determinant of child malnutrition there). Poverty (higher in South Asia), may also partially explain the regions' differences. Regardless of the levels of the determinants of child malnutrition that we have identified in this study, a large disparity in child malnutrition prevalences between the regions would persist. The source of this remaining difference is time-invariant factors specific to South Asian countries that we have been unable to identify explicitly. Examples might be the region's monsoon climate, high population densities, and deeply-entrenched beliefs regarding child feeding practices. An unraveling of this "black box" should also be the subject of further research.

Third, how important of a determinant of child malnutrition is food availability at a national level? We find national food availability to be a particularly important determinant of child malnutrition when it is at very low levels (below approximately 2,300 kilocalories). After a certain point (approximately 3,120 kilocalories), further improvements are unlikely to aid in reducing child malnutrition. For countries with such

[35] Note that simply maintaining the determinants at their 1995 levels will require substantial resources, particularly for national per capita food availability, which has to be maintained in the face of increasing populations and a fairly fixed amount of cultivable land.

high food availabilities, efforts to promote food security must be focused on promoting food access at the household level. The regions in which improved food availabilities have the most to contribute in the coming decades are South Asia and Sub-Saharan Africa.

Fourth, how important are women's status and education? This research report confirms the now overwhelming evidence of the strong impact of women's education on children's nutrition. The report also establishes that women's relative status is an important determinant of child malnutrition in all developing country regions. These findings confirm women's key role in the etiology of child nutrition, whether through the pathway of maternal and child care or household food security. Together, improvements in women's education and status alone contributed to over 50 percent of the reduction in child malnutrition that took place from 1970 to 1995. More emphasis should be placed on them in the future than has been in the past—especially on women's status and education in South Asia and women's education in Sub-Saharan Africa.

Fifth, how important are national political factors (such as democracy) and national incomes, and through what pathways do they affect child malnutrition? This report has established the existence of a significant link between the degree of democracy in countries and their prevalence of child malnutrition, with democracy working mainly through improving health environments and national food availability. Why it is important for these two underlying determinants and not for others needs to be better understood. Nevertheless, the analysis suggests that political variables have as valid a place in studies of malnutrition as they do in studies of economic growth. National income is an even more important determinant of child malnutrition than democracy. Increases in per capita national income have contributed to almost half of the total reduction in the developing-country child malnutrition prevalence of 1970-95, working via all four underlying determinants.

A key message of this paper is that any comprehensive strategy for attacking the problem of child malnutrition must include actions to address both its basic *and* underlying causes. If national incomes and democracy are not improved, the resources and political will necessary for investing in health environments, women's education and status, and food availabilities will not be available. If improved national incomes and democracy are not directed at improvements in the underlying determinants, on the other hand, they will make little difference.

Before concluding, we point to some limitations of the study. The first is our inability to adequately consider two factors believed to have a strong influence on child malnutrition: food security at the household level and poverty. With respect to the former, at the present time there are no cross-country comparable data on national rates of food insecurity from household survey data (Smith 1998b). In its place, we have employed per capita dietary energy supplies, an inadequate measure of food insecurity because they do not measure food access. With respect to poverty, while some data exist (World Bank 1998b), at present there are not enough to reliably estimate this variable's influence on child malnutrition. The second main limitation of this study is our inability to address the sequential nature of optimal interventions for improving child nutritional status. In many cases, one intervention, for example, provisioning of health services, will need to be undertaken before others will have any positive impact. Our estimation methodology limits us to estimating each explanatory variable's impact as if interventions were to take place simultaneously. A third limitation of the study is that we are unable to consider the cost-effectiveness of various interventions in the setting of policy priorities.

We can suggest several fruitful directions for future research. The first is to undertake the analysis for rates of stunting, which is a longer term measure of nutritional deprivation than is underweight. The second is to undertake estimations separately for male and female under-fives to determine if malnutrition among these groups is explained by different factors. Corresponding to the limitations identified, we see a need for future research into the sequencing of interventions to improve child nutrition and into the costs of various interventions to improve child nutrition. Fourth, a more in-depth understanding of the little-studied roles of democracy and women's status are needed. Fifth, the roles of debt and structural adjustment, conflict, and HIV/AIDS in Sub-Saharan Africa's rising malnutrition and of the time-invariant factors explaining South Asia's higher child malnutrition prevalence need to be investigated.

Finally, an indicator of national prevalences of food insecurity—based fully on household food consumption survey data—is needed for clarifying the role of this important determinant of child malnutrition and for identifying where food insecurity is located and how it changes over time. While in the past the task was held back by data availabilities, with the increased frequency of household food consumption surveys, the development of such an indicator is now possible.

In conclusion, we hope that this study will aid policymakers that have a broad international mandate to prioritize their resource investments in the goal of reducing and eventually eliminating malnutrition in the developing countries. We hope that it will instigate further investigation into the importance of the factors affecting child malnutrition that we have highlighted, particularly those that have received relatively little attention in the past: women's status and democracy.

We end with a caution to users of this study's findings: the results apply only at the very broad level of the developing countries as a whole and, more tentatively, to the developing-country regions. Their applicability to specific populations at more disaggregated levels is unknown. Careful analysis and diagnosis are needed for understanding the causes of child malnutrition for each subpopulation of the developing world, whether it be a country, a subnational region, a community, a household, or an individual child.

TABLES

Table 1. Trends in Developing-Country Child Malnutrition (Underweight) by Region, 1970-1995

	Percent Underweight							Numbers underweight						
Region	1970	1975	1980	1985	1990	1995	Change 1970-95	1970	1975	1980	1985	1990	1995	Change 1970-95
	(percent)							(millions of under-fives)						
South Asia	72.3	67.7	63.7	55.3	53.4	49.3	**-23.0**	96.7	90.6	89.9	87.2	95.4	86.0	**-10.7**
Sub-Saharan Africa	35.0	31.4	28.9	25.8	28.8	31.1	**-3.9**	20.6	18.5	19.9	20.9	25.7	31.4	**+10.8**
East Asia	39.5	33.3	30.0	28.8	23.5	22.9	**-16.6**	53.5	45.1	43.3	45.3	42.5	38.2	**-15.3**
Near East and North Africa	20.7	19.8	17.2	13	not available	14.6	**-6.1**	5.4	5.2	5.0	4.1	not available	6.3	**+0.9**
Latin America and the Caribbean	21.0	17.0	12.2	12.9	11.4	9.5	**-11.5**	10.1	8.2	6.2	6.3	6.2	5.2	**-4.9**
Total	46.5	41.6	37.8	34.3	32.3	31.0	**-15.5**	187.3	167.6	164.3	163.8	176.7	167.1	**-20.2**

Sources: 1975, 1980 and 1985 prevalences and numbers of malnourished children are from Table 1.2 of ACC/SCN (1992); 1990 and 1995 estimates are from WHO (1997), Table 6. The prevalences for 1970 are predicted using the underlying-determinant model regression results presented in Section 5.2.1 of this paper.

Notes: A child under five (0-59 months) is considered malnourished if the child falls below an anthropometric cutoff of -2 standard deviations below the median value of weight-for-age using National Center for Health Statistics/World Health Organization standards. ### 1970 numbers of underweight approximated using 1975 total numbers of children while awaiting estimates from UN Population Prospects 1996 Revision.

Table 2. Regional, Country and Population Coverage of the Study

Region	Number of Count-ries	Regional Coverage (in terms of number of countries)	Number of Obser-vations	Countries
South Asia	5	71%	16	Bangladesh(82, 85, 89, 96), India-rural(77, 91), Nepal-rural(75, 95), Pakistan(77, 85, 90, 95), Sri Lanka(77, 80, 87, 93).
Sub-Saharan Africa	26	58%	65	Benin(87, 96), Burkina Faso(87, 92), Cameroon(77, 91), Comoros(91, 95), Congo, Rep.(77, 87), Congo, Dem. Rep.(75, 86, 89, 94), Côte d'Ivoire(86, 94), Ethiopia-rural(83, 92), Ghana(87, 93), Guinea(80, 95), Kenya-rural(82, 87), Lesotho(76, 81, 94), Madagascar(83, 92, 95), Malawi(81, 92, 95), Mauritania(81, 87, 90), Mauritius(85, 95), Niger(85, 92), Nigeria(90, 93), Rwanda(76, 92), Senegal(86, 92), Sierra Leone(74, 77, 90), Tanzania(87, 91, 96), Togo(76, 88), Uganda(77, 88, 95), Zambia(72, 85, 88, 92, 96), Zimbabwe(84, 88, 94).
East Asia	8	57%	26	China(87, 92, 95), Indonesia(78, 87, 95), Laos(84, 94), Malaysia(83, 86, 90, 95), Myanmar(80, 83, 90, 95), Philippines(73, 82, 87, 93), Thailand(82, 87, 90), Vietnam(80, 87, 94).
Near East and North Africa (NENA)	5	31%	14	Algeria(87, 92, 95), Egypt(78, 88, 92, 95), Jordan(75, 90), Morocco(87, 92), Tunisia(74, 88, 94).
Latin America and the Caribbean (LAC)	19	68%	58	Bolivia(81, 89, 93), Brazil(75, 89, 96), Chile(78, 82, 86, 95), Columbia(77, 86, 89, 95), Costa Rica(78, 82, 89, 94), Dominican Republic(86, 91), El Salvador(88, 93), Guatemala(77, 80, 87, 95), Guyana(71, 81, 93), Haiti(78, 90, 94), Honduras(82, 87, 93), Jamaica(78, 85, 89, 93), Mexico-rural(74, 79, 89), Nicaragua(80, 93), Panama(80, 92), Peru(75, 84, 91, 96), Trinidad and Tobago(76, 87), Uruguay(87, 92), Venezuela(81, 87, 90, 94).
TOTAL	63	57%	179	
		(88 % of total developing world population)[a]		

[a] This percentage is calculated from countries' 1995 populations.

Note: See Appendix Table A8 for regional grouping of developing countries.

Table 3. Variable Definitions and Sample Summary Statistics

Variable	Definition	Mean	Standard deviation	Minimum	Maximum
Child Malnutrition (CHMAL)	Percent of children with weight-for-age less than 2 standard deviations from the mean according to NCHS/WHO standards (%)	24.6	15	0.9 (Chile 1995)	71.3 (India 1977)
Access to Safe Water (SAFEW)	Percent of population with access to safe water (%)	56.2	23.7	6 (Ethiopia 1983)	100 (Mauritius 1985)
Female Secondary Enrollments (FEMSED)	Gross female secondary school enrollment rate (%)	33.8	22.5	2.5 (Uganda 1977)	88 (Uruguay 1992)
Female to Male Life Expectancy Ratio (LFEXPRAT)	Ratio of female life expectancy at birth to male life expectancy at birth	1.062	0.03	0.97 (Nepal 1975)	1.15 (El Salvador 1988)
Per capita Dietary Energy Supply (DES)	Daily per capita dietary energy supply (kilo calories)	2360	331	1592 (Ethiopia 1992)	3284 (Egypt 1995)
Per capita National Income (GDP)	Per capita Gross Domestic Product (in purchasing power parity - adjusted 1987 U.S. dollars)	2306	1779	306 (Ethiopia 1992)	8612 (Chile 1995)
Democracy (DEMOC)	Combined index of political rights and civil liberties (measured on a scale of 1 to 7 points, 1=least democratic)	3.5	1.7	1[a]	7 (Costa Rica 1978, 1982, 1989)

[a] The countries for which the democracy index number is 1 are: Algeria (1995), Benin (1987), China (1992, 1995), Ethiopia (1983), Guinea (1980), Haiti (1994), Laos (1994), Mauritania (1995), Myanmar (1990, 1995), Uganda (1977),Vietnam (1980, 1987, and 1994), and Zaire (1986).

Table 4. Regional Comparison of Sample Underweight Prevalences and Explanatory Variable Means, 1970s-1990s

	Child Malnutrition (%) (1)	Access to Safe Water (%) (2)	Female Secondary Enrollments (%) (3)	Female to Male Life Expectancy Ratio (4)	Per capita Dietary Energy Supply (kilo calories) (5)	Per capita National Income ($PPP) (6)	Democracy (1=least democratic) (7)
South Asia	**61**	**60.5**	**23.8**	**1.010**	**2187**	**863**	**4.59**
1970s (n=4)	69.1	29.8	16.3	0.987	2023	728	4.38
1980s (n=6)	61.8	51.9	14.2	1.020	2042	719	3.25
1990s (n=6)	55.7	81.3	31.5	1.022	2332	990	5.16
Sub-Saharan Africa	**31**	**37.5**	**15.6**	**1.061**	**2164**	**879**	**2.57**
1970s (n=10)	27.2	24.7	8.5	1.069	2207	1358	1.77
1980s (n=26)	26.5	35.0	14.6	1.066	2117	1031	2.02
1990s (n=29)	33.7	40.4	17.0	1.060	2184	740	2.96
East Asia	**23**	**64.5**	**47.9**	**1.051**	**2595**	**1874**	**1.69**
1970s (n=2)	45.0	19.7	25.8	1.050	2007	1402	3.0
1980s (n=13)	26.8	63.8	39.2	1.053	2502	1483	2.30
1990s (n=11)	19.4	67.8	54.4	1.049	2686	2132	1.25
Near East/North Africa	**11**	**75.5**	**52.5**	**1.043**	**3058**	**2527**	**2.81**
1970s (n=3)	16.5	72.5	34.0	1.042	2710	1547	3.32
1980s (n=4)	10.1	69.3	46.4	1.043	3018	2746	3.09
1990s (n=7)	10.8	79.4	59.7	1.043	3157	2637	2.55
Latin America/Caribbean	**12**	**71.8**	**44.8**	**1.094**	**2647**	**4740**	**4.73**
1970s (n=12)	18.9	59.5	33.3	1.086	2620	4713	4.06
1980s (n=26)	11.4	79.0	47.2	1.096	2675	4871	5.14
1990s (n=20)	8.3	73.3	51.4	1.098	2636	4607	4.79

Note: The means reported in this table are calculated based only on the country-year pairs included in the study data set. They are population-weighted.

Table 5. Underweight Prevalences and Explanatory Variable Means, 1970s-1990s

	1970s	1980s	1990s	Change 1970s-1990s	% change 1970s-1990s
Child Malnutrition (%)	50.7	29.0	28.5	22.2	-43.8
Access to Safe Water (%)	36.3	61.6	69.0	32.7	+90
Female Secondary Enrollments (%)	21.7	34.5	45.0	23.3	+107
Female to Male Life Expectancy Ratio	1.024	1.055	1.047	0.023	+2.25
Per capita Dietary Energy Supply	2,187	2,440	2,564	377	+17.2
Per capita National Income	1,772	1,871	1,904	132	+7.45
Democracy (1=least democratic)	3.96	2.86	2.66	-1.3	-32.8
Number of observations	31	75	73	--	--
Number of countries	29	54	58	--	--

Note: The means reported in this table are calculated based only on the country-year pairs included in the study data set and therefore must be considered illustrative (see Table 11 for an alternative estimation of the changes in time using data on all of the study countries for consecutive five-year intervals). They are population-weighted.

Table 6. Regional Poverty Prevalences for 1987, 1990, and 1993

	1987	1990	1993
South Asia	45.4	43	43.1
Sub-Saharan Africa	38.5	39.3	39.1
East Asia	29.7	28.5	26
Near East and North Africa	4.7	4.3	4.1
Latin America and the Caribbean	22	23	23.5
TOTAL	33.9	32.9	31.9

Source: Ravallion and Chen (1996) Table 5

Note: The poverty measure employs an international poverty line of $1 per person per day at 1985 purchasing power parity.

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Table 7. Ordinary Least Squares and Country Fixed-Effects Estimation Results: Linear Specifications

	Ordinary Least Squares		Country Fixed-Effects		
	Underlying-Determinants (1)	Basic-Determinants (2)	Underlying-Determinants (3)	Basic-Determinants (4)	All Determinants (5)
Access to safe water (SAFEW)	-.139 (2.7)***		-.085 (2.14)**		-.069 (1.7)*
Female secondary enrollments (FEMSED)	-.068 (1.27)		-.167 (2.64)***		-.177 (2.78)***
Female-to-male life expectancy ratio (LFEXPRAT)	-177 (5.23)***		-93.45 (2.25)**		-111 (2.6)**
Per capita dietary energy supply (DES)	-.012 (3.65)***		-.0081 (2.48)**		-.0077 (2.21)**
Per capita national income (GDP)		-.0048 (8.2)***		-.0023 (2.46)**	1.20 E-04 (.137)
Democracy (DEMOC)		-.274 (.44)		-.884 (1.67)*	-.779 (1.68)*
R-Squared	.433	.346	.943	.916	.945
Adjusted R-Squared	.420	.338	.910	.869	.910

Notes: The dependent variable is prevalence of child malnutrition. The number of observations for all regressions is 179 (63 countries). Absolute values of t-statistics are given in parentheses. * indicates significance at the 10% level; ** indicates significance at the 5 percent level; ***indicates significance at the 1 percent level.

Table 8. Country Fixed-Effects Estimation Results: Non-Linear Specifications

	Quadratic DES and GDP Curves		Three-Segment Linear Spline DES and GDP Curves	
	Underlying Determinants (1)	Basic Determinants (2)	Underlying Determinants (3)	Basic Determinants (4)
Access to safe water (SAFEW)	-.072 (1.84)*		-.076 (1.95)*	
Female secondary enrollments (FEMSED)	-.232 (3.51)***		-.220 (3.41)***	
Female-to-male life expectancy ratio (LFEXPRAT)	-74.89 (1.83)*		-71.8 (1.74)*	
Per capita dietary energy supply (DES)	-.067 (3.00)***			
DES-squared	1.24 E-05 (2.66)***			
DES Spline DES ≤ 2300 (n=93)			-.0170 (3.41)***	
2300< DES≤3120 (n=83)			-.0024 (2.16)**	
DES > 3120 (n=3)			.0405 (1.35)	
Per capita national income (GDP)		-.0121 (4.68)***		
GDP-squared		9.67 E-07 (4.03)***		
GDP Spline GDP ≤ 800 (n=37)				-.0444 (3.15)***
800< GDP≤ 4725 (n=118)				-.0067 (2.63)***
GDP > 4725 (n=24)				.0006 (3.37)***
Democracy (DEMOC)		-1.45 (2.81)***		-1.27 (2.51)**
R-Squared	.947	.927	.947	.930
Adjusted R-Squared	.914	.884	.914	.889

Notes: The dependent variable is prevalence of child malnutrition. The coefficients on the fixed-effects terms are not shown. The number of observations for all regressions is 179 (63 countries). Absolute values of t-statistics are given in parentheses. * indicates significance at the 10 percent level; ** indicates significance at the 5 percent level; ***indicates significance at the 1 percent level.

Table 9. Country Fixed-Effects Estimates of the Effects of Per capita National Incomes and Democracy on Underlying-Determinant Explanatory Variables

	Access to Safe Water (SAFEW) (1)	Female Secondary Enrollments (FEMSED) (2)	Female to Male Life Expectancy Ratio (LFEXPRAT) (3)	Per capita Dietary Energy Supply (DES) (4)
Per capita national income (GDP)	.0174 (2.85)***	.0148 (3.71)***	1.0 E-05 (1.90)*	.4105 (6.26)***
GDP-squared	-1.31 E-06 (2.31)**	-9.32 E-07 (2.53)**	-8.2 E-10 (1.67)*	-2.79 E-05 (4.59)***
Democracy (DEMOC)	3.49 (2.87)***	.981 (1.23)	-.002 (1.57)	26.28 (2.0)**
R-Squared	.835	.922	.901	.902
Adjusted R-Squared	.740	.877	.845	.846

Notes: The number of observations for all regressions is 179 (63 countries). Absolute values of t-statistics are given in parentheses. * indicates significance at the 10 percent level; ** indicates significance at the 5 percent level; ***indicates significance at the 1 percent level.

Table 10. Instrumental Variable Candidates for Hausman-Wu Endogeneity Tests

Explanatory Variable	Candidate Instrument	Rationale for Instrument Choice	Data Source	Correlation between instrument and variable[a]
Population with access to safe water (SAFEW)	(1) Annual internal renewable freshwater resources per capita	Freshwater availability is unlikely to affect child malnutrition other than through provision of safe water.	World Resources Institute (various years)	0.19 (p=.043)
Female secondary enrollments (FEMSED)	(2) Male gross primary enrollments	Current male primary enrollments unlikely to be contemporaneously correlated with malnutrition of under-fives, yet to be correlated with female secondary enrollments through the value placed on education and through its availability.	UNESCO(1998)	0.55 (p=.000)
Female-Male Life Expectancy Ratio (LFEXPRAT)	(3) Percent of births attended by health staff	Births attended by health staff likely to be (positively) correlated with female life expectancy through reduced maternal mortality yet not to affect the nutritional status of surviving children.	UNICEF State of the World's Children (various years) and World Bank (1997a)	0.39 (p=.000)
Per capita dietary energy supply (DES)	(4) Arable land per capita	Land availability is a constraining factor in agricultural production; However, could affect child malnutrition through raising incomes from non-food production.	FAO (1998)	-0.10 (p=.17)
	(5) Land under cereal production per capita	Land employed as an input into cereal production raises food production. My affect child malnutrition other than through DES by raising incomes.	FAO (1998)	-0.19 (p=.014)
	(6) Fertilizer use per hectare of arable land	Fertilizer use increases agricultural yields; May affect child malnutrition other than through DES by raising incomes or causing illness in children due to leakage of contaminants into water tables.	FAO (1998)	0.49 (p=.000)
	(7) Irrigated land per capita	The use of irrigation increases agricultural yields; However, could affect child malnutrition other than through DES by raising household incomes.	FAO (1998)	0.20 (p=.009)
Per capita Gross Domestic Product (GDP)	(8) Real investment share of GDP	As per Pritchett and Summers (1996).	World Bank (1997a, 1998)	0.31 (p=.000)
	(9) Foreign investment share of GDP	As per Pritchett and Summers (1996).	World Bank (1997a, 1998)	0.25 (p=.001)
	(10) Economic openness measure	Economic openness may improve national income but not otherwise affect child malnutrition.	Penn World Tables	0.07 (p=.367)
Democracy (DEMOC)	No candidate identified.	--	--	--

[a] Pearson correlation coefficient between nonmissing values for entire sample. If the p-value (given in parentheses) is greater than 0.1, the correlation is considered to be statistically insignificant.

Table 11. Results of Endogeneity Tests

Explanatory Variable	Instrumental Variable(s)	Number of observ-ations	Relevance[a] (3)		Overidentification[b] (4)		Hausman-Wu[c] (5)	
			F statistic	Test passed?	χ^2 statistic	Test passed?	t statistic	Test passed?
Population with access to safe water (SAFEW)	Water resources	94	3.4*	yes	--	--	1.2	yes
Female secondary enrollments (FEMSED)	Male primary enrollments	179	0.67	no	--	--	--	not performed
Female-to-male life expectancy ratio (LFEXPRAT)	Birth attendance by health staff	92	0.46	no	--	--	--	not performed
Per capita dietary energy supply (DES)	Land in cereal, fert-ilizer use, irrigated land	163	2	no	--	--	--	not performed
	Fertilizer use, irrigated land	177	3.1**	yes	0.7	yes	1.4	yes
Per capita national income (GDP)	Investment share and foreign investment share of GDP	164	8.9***	yes	0.35	yes	-0.27	yes

Notes: These tests are only performed for the fixed-effects model specifications, with quadratic terms representing nonlinearities.

[a] The null hypothesis is that the instrument set z in a regression of the potentially endogenous variable on the exogenous variables and z is not (jointly) significant. If F is greater than the critical value of the F-distribution for 1% (***), 5% (**), or 10% (*) level tests, then the null hypothesis is rejected.

[b] The null hypothesis is that the model is correctly specified (the instruments should not be included in the list of explanatory variables) and the instruments z are uncorrelated with the error term in the CHMAL equation. The chi-squared statistic is equal to $n*R^2$, where n is the number of observations and R^2 is from a regression of the predicted residuals from Two Stage Least Squares estimation of the original CHMAL regression on the exogenous variables plus z. This test can only be performed when there is more than one instrument available for the variable being tested. It is not possible to perform the test using the non-linear (quadratic) specifications because DES and GDP are too highly correlated with their squares. The test results reported are for the associated linear models. We assume that if the instruments for the variables pass the test in the linear models, then they are uncorrelated with the error term in the non-linear models.

[c] The null hypothesis being tested is that the Instrumental Variable and fixed-effects estimates are different, indicating endogeneity of the variable. The null hypothesis is rejected if the predicted residuals from a regression of the endogenous variable on the exogenous variables and instruments are insignificant when included in a regression of CHMAL on all explanatory variables. The statistics are corrected using a procedure laid out in Haddad et al. 1995.

Table 12. How Strong Are the Effects on Child Malnutrition? Elasticities and Related Statistics for their Interpretation

	sample (or segment) mean (1)	**Elasticity[a] evaluated at sample mean (2)**	developing-country range[b] (3)	**Increase in variable needed to reduce prevalence of child malnutrition by one percentage point[c] (4)**	number in (5) as a percent of developing-country range (5)
Underlying-Determinant Variables					
Population with access to safe water (SAFEW)	56.2	**-0.174**	1 - 100	**13.1**	13.2
Female secondary enrollments (FEMSED)	33.8	**-0.302**	0.5 - 100	**4.6**	4.6
Female-to-male life expectancy ratio (LFEXPRAT)	1.0624	**-3.092**	0.97 - 1.12	**0.0139**	9.3
Per capita dietary energy supply (DES)	2360	**-0.949**	1,522 - 3,605	**101**	4.9
DES≤2300	2106	**-1.150**		**59**	2.8
2300<DES≤3120	2613	**-0.343**		**425**	20.4
DES > 3120	3230	**0**		**--**	--
Basic-Determinant Variables					
Per capita national income (GDP)	2306	**-1.26**	300 - 8612	**74.1**	0.89
GDP ≤ 800	645	**-0.740**		**23**	0.3
800< GDP≤ 4725	2102	**-0.605**		**150**	1.8
GDP > 4725	5867	**0.329**		**--**	--
Democracy (DEMOC)	3.5	**-0.181**	1 - 7	**0.79**	13.1

[a] Estimated percent change in CHMAL resulting from a 1 percent increase in the explanatory variable based on estimates of Table 8, columns (3) and (4). The segment elasticities for DES and GDP are evaluated at the variable and CHMAL means for the data falling within the segments.

[b] The endpoints of the developing country ranges are for the following countries and years (min, max): SAFEW (Gabon 1970; Barbados 1990s), FEMSED (Mauritania 1970; Bahrain 1993); LFEXPRAT (Nepal 1975, max: Brazil 1996 and El Salvador 1993). Note: These numbers are only based on this study's sample and the maximum value for the sample, that of 1.15 for El Salvador in 1988 is excluded); DES (Ethiopia 1977, Turkey 1995); GDP (Ethiopia 1992; Chile 1995); DEMOC (see Table 3 for examples from this study's sample).

[c] Calculated as 1 divided by the regression coefficients of Table 8, columns (3) and (4).

Table 13. Estimated Regression Coefficients for Dietary Energy Supply Per capita and Gross Domestic Product Per capita by Region (1970-95)

	Dietary Energy Supply Per Capita		Gross Domestic Product Per Capita	
	mean (1)	coefficient (2)	mean (3)	coefficient (4)
South Asia	2,187	-0.0133	863	-0.0255
Sub-Saharan Africa	2,164	-0.0140	879	-0.0222
East Asia	2,595	-0.0085	1,874	-0.0090
Near East and North Africa	3,058	-0.0019	2,527	-0.0067
Latin America and the Caribbean	2,647	-0.0069	4,740	-0.0040
Full Sample[a]	2,360	-0.0099	2,306	-0.0135

Notes: The coefficients are calculated as a weighted average of the segment coefficients, where the weights are the proportion of the sample data points of the region falling into each segment.

[a] While the regional means are population-weighted, the full sample means are not (see Table 3).

Table 14. Dynamic Estimation Results—Basic Determinants

	Ordinary Least Squares	Country Fixed-Effects	
		Without time trend and initial conditions	With time trend and initial conditions
	(1)	(2)	(3)
Lagged Child Malnutrition	.76 (19.3)***	.290 (1.41)	.454 (.941)
Per capita National Income (GDP)	-.001 (2.92)***	-.745 (1.0)	-.0016 (.95)
Democracy (DEMOC)	-.931 (2.64)***	-.0008 (.61)	-1.27 (1.32)
Time trend (t)			.52 (1.33)
t*GDP0			.0006 (.87)
t*DEMOC0			-.903 (1.57)
R-Squared	.856	.0605	.1102
# Countries	63	36	36
# Observations	116	54	54

Note: The dependent variable is the prevalence of underweight children under five. Absolute values of t-statistics are given in parentheses. The fixed-effects models are estimated with the constant term suppressed. Thus the R-Squared statistic measures the proportion of variability in the dependent variable about the origin explained by each regression. It cannot be compared to the R-Squared statistics for the previous models since they included intercept terms. In the fixed-effects model, first-differenced lagged child malnutrition is instrumented with child malnutrition lagged two periods to correct for correlation of the term with the fixed-effect component of the error term.

Table 15. Dynamic Estimation Results—Underlying Determinants

	Ordinary Least Squares	Country Fixed-Effects	
	Without initial conditions (1)	Without time trend and initial conditions (2)	With time trend and initial conditions (3)
Lagged Child Malnutrition	.756 (19.0)***	.284 (.924)	.629 (1.31)
Health Environment (SAFEW)	-.074 (2.29)**	.021 (.27)	-.011 (.11)
Women's Education (FEMSED)	-.042 (1.3)	.014 (.36)	.009 (.18)
Women's Relative Status (LFEXPRAT)	-32.2 (1.4)	-165 (1.87)*	-148 (1.33)
Per capita Food Availability (DES)	-.0012 (.60)	-.0083 (1.3)	-.009 (1.14)
Time trend (t)			-.199 (.42)
t*SAFEW0			-.089 (1.33)
t*FEMSED0			.014 (.21)
t*LFEXPRAT0			-8.21 (1.03)
t*DES0			.007 (1.84)*
R-Squared	.854	.1472	.2097
# Countries	63	36	36
# Observations	116	54	54

Note: The dependent variable is the prevalence of underweight under fives. Absolute values of t-statistics are given in parentheses. Please refer to notes for the previous table.

Table 16. Explanatory Variable Means, 1970, 1975, 1980, 1985, 1990, and 1995

	1970 (1)	1975 (2)	1980 (3)	1985 (4)	1990 (5)	1995 (6)	Absolute change 1970-95 (7)	Average annual change 1985-95 (8)
Underlying-Determinant Variables								
Population with access to safe water (%)	30.2	45.4	52.4	60.7	69.9	70.3	40.1	0.96
Female secondary enrollments (%)	15.6	25.4	28.4	30.6	36.4	46.6	31.0	1.6
Female-to-male life expectancy ratio	1.022	1.026	1.033	1.040	1.045	1.048	0.024	0.0008
Female life expectancy (years)	55.2	58.5	60.4	63.5	65.3	66.0	10.79	0.25
Male life expectancy (years)	54.0	56.9	58.5	60.8	62.4	63.0	9.04	0.22
Per capita dietary energy supply (kilocalories)	2092	2089	2226	2380	2472	2559	467	17.9
Basic-Determinant Variables								
Per capita national income (PPP $ US)	1011	1163	1361	1378	1673	2121	1111	44.8
Democracy (1=least democratic)	2.85	2.99	3.75	3.31	3.24	2.71	-0.14	-0.06

Note: These data are population-weighted. They are estimated from data for the countries in the data set only (Comoros was dropped from the sample due to the absence of population data).

Table 17. Estimated Contributions of Underlying and Basic Determinants to Changes in the Prevalence of Child Malnutrition by Region, 1970-1995

	All Regions (1)	South Asia (2)	Sub-Saharan Africa (3)	East Asia (4)	Near East and North Africa (5)	Latin America and the Caribbean (6)
	(percentage-point change in underweight rate)					
Underlying Determinants						
(1) Health environment	-3.06	-4.56	-2.07	-2.74	-0.45	-1.80
(2) Quality of care for mothers and children						
a) Women's education	-6.82	-4.61	-3.39	-9.27	-9.64	-6.98
b) Women's relative status	-1.84	-3.85	+1.27	-1.36	+0.28	-1.65
(3) National food availability (proxy for food security[a]	-4.14	-3.44	-0.048	-6.11	-2.34	-0.77
(4) **Total Percentage-Point Change**	**-15.86**	**-16.46**	**-4.24**	**-19.48**	**-12.43**	**-11.20**
Basic Determinants[b]						
(5) National Income[a]	-7.39					
(6) Democracy	+0.18					
(7) **Total Percentage-Point Change**	**-7.22**					

Notes: The estimates in this table are obtained by multiplying the coefficients on the proxy variables for each determinant (Table 8) by the change in the proxy from 1970-1995. The changes are obtained from Appendix Tables A3-A7. The proxy for each determinant (identified by row number) is: (1) access to safe water; (2) female secondary enrollments; (3) female-to-male life expectancy ratio; (4) per capita dietary energy supply; (6) per capita gross domestic product; and (7) democracy index (see Table 3 for definitions of the variables).

[a] These estimates take into account the changing coefficient on the variable as its level changes.
[b] As discussed in Section 5.2.3, the regression coefficients of the basic determinants model cannot be applied to the regions separately due to fundamental structural differences across the regions.

Table 18. 2020 Projections of the Prevalence and Numbers of Malnourished Children in Developing Countries, Alternative Scenarios

	1995 mean (1)	Annual increase in variable 1985-95 (2)	2020 Scenarios: Status Quo (3)	2020 Scenarios: Pessimistic (4)	2020 Scenarios: Optimistic (5)
(1) Prevalence of child malnutrition (%)	31	--	18.4	21.8	15.1
(2) Numbers of children malnourished (millions of under-fives)	167.1	--	140.3	154.8	127.6
(3) Access to safe water	70.2	0.96 percentage points	94.3	88.3	100
(4) Female secondary enrollments	46.6	1.60 percentage points	86.7	76.7	96.7
(5) Female-to-male life expectancy ratio	1.047	0.00071	1.066	1.061	1.07
(6) Per capita dietary energy supply (DES)	2559	--	2821	2662	2978

Notes: The estimates in rows (3) through (5) are based on 1985-95 average annual growth rates (column 2) calculated from the reported values of the respective variables given in columns (4) and (6) of Table 16. In the status quo scenario the rates are assumed to remain the same for the period 1995-2020. In the pessimistic scenario they are assumed to fall by 25%. In the optimistic scenario they are assumed to increase by 25%. In the case that a variable hits its maximum, the estimated value for 2020 is replaced by the maximum. This is the case for the value given for SAFEW in the optimistic scenario. The estimates for DES in row (6) are based on IFPRI IMPACT model projections as reported in Rosegrant et al. (1995). The projections correspond to future developments in food prices, agricultural productivity, research investments, population growth and growth in nonagricultural incomes (see text for a full explanation).

Table 19. 2020 Projections of the Prevalence and Numbers of Malnourished Children in Developing Countries, Alternative Scenarios By Region

Region	Percent Underweight				Numbers underweight			
	1995	2020 Status Quo	2020 Pessimistic	2020 Optimistic	1995	2020 Status Quo	2020 Pessimistic	2020 Optimistic
	percent of under fives				millions of under fives			
South Asia	49.3	37.4	40.3	34.5	86.0	66.0	71.1	60.9
Sub-Saharan Africa	31.1	28.8	32.4	25.7	31.4	48.7	54.6	43.3
East Asia	22.9	12.8	13.1	12.6	38.2	21.4	21.9	20.9
Near East and North Africa	14.6	4.97	7.4	3.7	6.3	3.2	4.8	2.4
Latin America and the Caribbean	9.5	1.92	4.0	0	5.2	1.1	2.3	0
All Developing Countries	31.0	18.4	21.8	15.1	167.1	140.3	154.6	127.6

Notes: The estimates are based on projected future values of the underlying-determinant explanatory variables SAFEW, FEMSED, LFEXPRAT and DES defined in Table 3. Future values of the first three are based on 1985-95 average annual growth rates calculated from the reported values of the respective variables given in columns (4) and (6) of Appendix Tables A3 through A7. In the status quo scenario the rates are assumed to remain the same for the period 1995-2020. In the pessimistic scenario they are assumed to fall by 25%. In the optimistic scenario they are assumed to increase by 25%. In the case that a variable hits its maximum, the estimated value for 2020 is replaced by the maximum. For South Asia this occurred for the variable SAFEW for all scenarios. For East Asia, it occurred for the variable FEMSED for all scenarios. For the Near East and North Africa it occurred for SAFEW for all scenarios and for FEMSED for the optimistic scenario only. Projections of DES are based on IFPRI IMPACT model projections as reported in Rosegrant et al. (1995). They correspond to future developments in food prices, agricultural productivity, research investments, population growth and growth in nonagricultural incomes (see text for a full explanation).

Table 20. Strength of Impact of National Food Availability on Child Malnutrition: Country Groupings by High, Medium, and Low Impact

	High Impact (DES[a] less than 2300)	Medium Impact (DES between 2300 and 3120)	Low Impact (DES greater than 3120)
South Asia	Afghanistan, Bangladesh, Nepal, Sri Lanka	Pakistan, India, Maldives	
Sub-Saharan Africa	Ethiopia, Somalia, Eritrea, Burundi, Mozambique, Comoros, Congo--Democratic Republic, Central African Republic, Chad, Djibouti, Angola, Zambia, Niger, Zimbabwe, Madagascar, Kenya, Tanzania, Sierra Leone, Rwanda, Malawi, Liberia, Lesotho, Togo, Namibia, Congo, Guinea, Sao-Tome and Principe, Mali, Cameroon, Burkina Faso, Botswana, Uganda, Gambia	Cote d'Ivoire, Sudan, Benin, Guinea-Bissau, Senegal, Swaziland, Gabon, Nigeria, Ghana, Mauritania, Mauritius	
East Asia	Cambodia, Mongolia, Laos	Thailand, Philippines, Korea--DP, Vietnam, Myanmar, China, Brunei, Malaysia, Macau, Indonesia	South Korea
Near East/N. Africa	Yemen, Iraq	Saudi Arabia, Jordan, Iran, Kuwait, Algeria, Tunisia	Morocco, Libya, Egypt, Lebanon, Syria, United Arab Emirates, Cyprus, Turkey
Latin America/ Caribbean	Haiti, Bolivia, Peru, Guatemala	Nicaragua, Dominican Republic, Honduras, Cuba, Venezuela, Ecuador, Guyana, Panama, Bahamas, Paraguay, El Salvador, Surname, Jamaica, Trinidad and Tobago, Chili, Colombia, Uruguay, Belize, Costa Rica, Brazil, Dominica, Argentina	Mexico, Barbados

Notes: The country classifications are based on cutoffs determined by the two knots of a three-segment linear spline function for DES in a regression on underweight prevalence (see Table 8, column 3). The DES's are for 1995. The source is FAO (1998).

[a] DES = Per capita Dietary Energy Supply measured in kilocalories.

Table 21. Comparison of the Strengths and Potential Impacts of the Determinants of Child Malnutrition (CHMAL)

	1995 mean (1)	**Increase in variable needed to reduce prevalence of child malnutrition by 1 percentage point (2)**	Number in (2) as a percent of developing-country range[a] (3)	Percent Determinant is below its desirable level[b] (0-100 scale) (4)	**Change in prevalence of child malnutrition with increase in determinant to desirable level[c] (5)**
Underlying Determinant Variables					**(percentage points)**
South Asia (1995 CHMAL: 49.3%)					
Safe water (SAFEW)	79.7	**13.1**	13.2	-20.3	**-1.6**
Female secondary enrollments (FEMSED)	34.1	**4.6**	4.6	-65.9	**-14.5**
Female to male life expectancy ratio (LFEXPRAT)	1.023	**0.0139**	9.3	-58.9	**-5.5**
Per capita dietary energy supply (DES)	2356	**94**	4.5	-46.5	**-3.9**
Sub-Saharan Africa (1995 CHMAL: 31.1%)					
SAFEW	48.8	**13.1**	13.2	-51.2	**-3.9**
FEMSED	19	**4.6**	4.6	-81.0	**-17.8**
LFEXPRAT	1.054	**0.0139**	9.3	-35.2	**-3.3**
DES	2136	**75**	3.6	-60.2	**-5.6**
East Asia (1995 CHMAL: 22.9%)					
SAFEW	66.5	**13.1**	13.2	-33.5	**-2.6**
FEMSED	59.8	**4.6**	4.6	-40.2	**-8.8**
LFEXPRAT	1.0514	**0.0139**	9.3	-37.4	**-3.5**
DES	2720	**188**	9.0	-23.8	**-2.1**
Near East/Nth Africa (1995 CHMAL: 14.6%)					**(percentage points)**
SAFEW	81.5	**13.1**	13.2	-18.5	**-1.4**
FEMSED	57.9	**4.6**	4.6	-42.1	**-9.2**
LFEXPRAT	1.044	**0.0139**	9.3	-42.8	**-4.0**
DES	3172	**333**	16	+4.5	**-0.7**
Latin Am/Caribbean (1995 CHMAL: 9.5%)					
SAFEW	77.3	**13.1**	13.2	-22.7	**-1.7**
FEMSED	56.5	**4.6**	4.6	-43.5	**-9.6**
LFEXPRAT	1.098	**0.0139**	9.3	-1.9	**-0.18**
DES	2777	**234**	11.2	-20.2	**-1.5**
Basic Determinant Variables[d]					
Per capita national income	2121	202	9.7	-59.1	**-18.5**
Democracy	2.71	0.79	11.5	71.5	**-5.5**

Note: The table compares the relative strengths of the underlying determinants among one another and the basic determinants among one another. Since the two groups lie at different levels of causality, it is important not to compare the results for variables *across* the groups.

[a] See Table 12 for variable ranges.

[b] The desirable levels of the variables are: SAFEW: 100%; FEMSED: 100%; LFEXPRAT: 1.1 (this is the average of the highest 20% of country-year data points in our sample in terms of female-to-male life expectancy ratios [excluding the highest, which is 1.15 and far above the next highest, 1.12]); DES: 3100 (see text footnote for rationale); GDP: We set the desirable level at $4750. This is the level past which improvements in GDP per capita no longer contribute to reductions in child malnutrition (see Section 5.2.1.3); DEMOC: 7 (the maximum value of the index).

[c] These numbers are calculated using the regression coefficients in Table 8 columns (3) and (4). For DES and GDP, each group's number is calculated using country averages (with the countries including all countries listed in Table A8--note: GDP will be expanded to all).

[d] Because the structural relationship between CHMAL and basic determinants differs by regions, we cannot provide reliable regional break downs.

Table 22. Priorities by Region For Future Child Malnutrition Reduction (Underlying Determinants)

Region	Rank of determinants by most potent impact on malnutrition relative to its existing range (1)	Rank of determinants by most potential for impact based on increases to desirable levels (2)	Top Priorities (3)
South Asia	1. Food availability 2. Women's education 3. Women’s relative status 4. Health Environment	1. Women's education 2. Women’s relative status 3. Food availability 4. Health Environment	1. Food Availability 1. Women's education
Sub-Saharan Africa	1. Food availability 2. Women's education 3. Women’s relative status 4. Health Environment	1. Women's education 2. Food availability 3. Health Environment 4. Women’s relative status	1. Food availability 1. Women's education
East Asia	1. Women's education 2. Food Availability 3. Women’s relative status 4. Health Environment	1. Women's education 2. Women’s relative status 3. Health Environment 4. Food availability	1. Women's education 2. Food Availability 2. Women’s relative status
Near East and North Africa	1. Women's education 2. Women’s relative status 3. Health Environment 4. Food availability	1. Women's education 2. Women’s relative status 3. Health Environment 4. Food availability	1. Women's education 2. Women’s relative status
Latin America and the Caribbean	1. Women's education 2. Women’s relative status 3. Food availability 4. Health Environment	1. Women's education 2. Health Environment 3. Food Availability 4. Women’s relative status	1. Women's education 2. Women’s relative status 2. Health Environment

Notes: The rankings in column (1) are based on the numbers reported in Table 21, Column (3). The rankings in column (2) are based on the numbers reported in Table 21, column (5). The top priorities in Column (3) are based on the highest ranked determinants in columns (1) and (2).

BOX TABLES

Box Table 1. Trends in the Determinants of Child Malnutrition in Sub-Saharan Africa 1985-95

	1985	1995
Child malnutrition (%)	25.8	31.1
Access to safe water (%)	33.5	48.8
Female secondary enrollments (%)	16.4	19.0
Female to male life expectancy ratio	1.066	1.054
Per capita dietary energy supply (kilocalories)	2035	2136
Per capita national income (PPP $US)	830	778
Democracy	2.01	2.44
Poverty (%, 1993)	38.5 (1983)	39.1 (1993)

Sources: Table 1, Appendix Table A4 and Table 6.
Note: These data are population-weighted means over all countries in the data set in each region.

Box Table 2. The Determinants of Child Malnutrition: A Comparison of South Asia and Sub-Saharan Africa (1995)

	South Asia	Sub-Saharan Africa
Child malnutrition (%)	49.3	31.1
Access to safe water (%)	79.7	48.8
Female secondary enrollments (%)	34.2	19
Female to male life expectancy ratio	1.023	1.054
Per capita dietary energy supply (kilocalories)	2356	2136
Per capita national income (PPP $US)	1136	778
Democracy	4.10	2.44
Poverty (%, 1993)	43.1	39.1

Sources: Table 1, Table 6, and Appendix Tables A3 and A4.
Note: These data are population-weighted means over all countries in the data set in each region.

APPENDIX 1
SUPPLEMENTARY TABLES

Table A1. Cross-Country Studies of the Determinants of Health Outcomes in Developing Countries

Study	Dependent Variable	Method	Number of countries	Main Findings	Limitations
Anand and Ravallion (1993)	Life expectancy, around 1985	OLS	22	Per capita income loses its significance as an explanatory variable once poverty and public spending on social services are controlled for.	Limited list of dependent variables may cause omitted variable bias. Small sample size. OLS estimation may lead to biased estimates
Subbarao and Raney (1995)	Infant mortality, 1985	OLS	72	Female education (lagged 5 and 10 years) has a strong effect on IMR; access to family planning, pop. per physician, and GDP per capita are significant but not as effective.	OLS estimation may lead to biased estimates. Mixed estimation of basic and underlying determinants only gives partial (rather than total) effect of basic determinants.
Pritchett and Summers (1996)	Infant and child mortality, life expectancy, 1960-1985	OLS, first-differences, country fixed-effects, and instrumental variables.	58-111 (184-368)[a]	Per capita GDP has a substantial positive impact on infant and child health; education levels are also important.	Does not allow breakdown of the pathways through which average incomes influence health outcomes. Since GDP per capita facilitates educational investment, coefficient on GDP may not represent total income effect (biased downwards).

Notes: OLS = Ordinary least squares regression.
[a] Total number of observations.

Table A2. Cross-Country Studies of the Determinants of Child Malnutrition in Developing Countries

Study	Dependent Variable	Method	Number of countries	Main Conclusion	Limitations
ACC/SCN (1993)	Underweight children, 1975-1992	OLS on pooled, cross-section data	66 (100)[a]	Energy availability, female education, public expenditures on social services and size of the child population under five all important determinants; regional effects are statistically significant (South Asia*kcal significant).	OLS estimation may give biased estimates.
ACC/SCN (1994)	Underweight children, 1975-1993	Quasi first-differences	35 (79)	Growth in per capita income is an important determinant.	Small sample size.
Gillespie, Mason and Martorell (1996)	Change in prevalence of underweight children (1975-1993)	Quasi first-differences	35 (# of spells)	Growth in per capita income and (levels of) public expenditures on health services are significant determinants; energy availability (levels and changes) is not significant.	Mixture of levels and change variables does not allow interpretation of coefficient estimates.
Rosegrant et al. (1995)	Underweight children 1980-1990	OLS on pooled, cross-section data	61 (183)	Energy availability and social expenditures are significantly (negatively) associated with underweight rates, but female education and access to safe water are not.	Use of predicted values from previous estimates means that significance and magnitude of parameter estimates are inaccurate.
Osmani (1997)	Stunted children, around 1990	OLS	45	Per capita income and female literacy are important determinants of stunting; income distribution is not significant; low birthweight accounts for South Asia's excessive malnutrition	Inclusion of "low birthweight" variable in estimating equation and OLS estimation technique lead to biased parameter estimates.
Frongillo et al. (1997)	Stunted and wasted children, post 1980	OLS	70	Energy availability, female literacy and per capita GNP significant determinants; results on health services differ by region. Female literacy squared, immunization rates, military population and energy availability (only for Asia) significant for wasting.	OLS estimation may give biased parameter estimates. Mixed estimation of basic and underlying determinants only gives partial (rather than total) effect of basic determinants.

Notes: OLS = Ordinary least squares regression.
[a] Total number of observations.

Table A3. Explanatory Variable Means (1970, 1975, 1980, 1985, 1990, and 1995), South Asia

	1970 (1)	1975 (2)	1980 (3)	1985 (4)	1990 (5)	1995 (6)	Absolute Change 1970-95 (7)
Population with access to safe water (%)	19.8	39.3	50.5	53.7	80.9	79.7	+59.8
Female secondary enrollment rate (%)	13.7	14.8	18.0	23.5	29.5	34.2	+21
Ratio of female life expectancy to male life expectancy	.970	.982	.992	1.00	1.014	1.023	+0.0537
Per capita dietary energy supply (kilocalories)	2105	1948	1975	2126	2264	2356	+251
Per capita gross domestic product (PPP $US)	674	682	724	768	962	1136	+461
Democracy index (1=least democratic)	5.17	5.17	5.48	4.83	5.24	4.10	-1.07

Note: These data are population-weighted means over all countries in the data set in the region.

Table A4. Explanatory Variable Means (1970, 1975, 1980, 1985, 1990, and 1995) Sub-Saharan Africa

	1970 (1)	1975 (2)	1980 (3)	1985 (4)	1990 (5)	1995 (6)	Absolute Change 1970-95 (7)
Population with access to safe water (%)	21.6	26.6	29.8	33.5	42.9	48.8	+27.2
Female secondary enrollment rate (%)	3.6	6.5	10.6	16.4	15.8	19.0	+15.4
Ratio of female life expectancy to male life expectancy	1.072	1.070	1.069	1.066	1.058	1.054	-0.0177
Per capita dietary energy supply (kilocalories)	2133	2083	2089	2035	2099	2136	+2.8
Per capita gross domestic product (PPP $US)	950	1000	963	830	851	778	-172
Democracy index (1=least democratic)	2.26	2.45	3.10	2.01	2.13	2.44	+0.184

Note: These data are population-weighted means over all countries in the data set in the region (excluding Comoros, for whom population data are not available).

Table A5. Explanatory Variable Means (1970, 1975, 1980, 1985, 1990, and 1995), East Asia

	1970 (1)	1975 (2)	1980 (3)	1985 (4)	1990 (5)	1995 (6)	Absolute Change 1970-95 (7)
Population with access to safe water (%)	30.5	46.2	52.6	68.4	67.1	66.5	+35.9
Female secondary enrollment rate (%)	17.7	34.8	36.3	34.3	42.0	59.8	+42.2
Ratio of female life expectancy to male life expectancy	1.032	1.032	1.038	1.048	1.051	1.051	+0.0189
Per capita dietary energy supply (kilocalories)	1998	2067	2280	2530	2618	2720	+722
Per capita gross domestic product (PPP $US)	628	739	938	1138	1582	2494	+1866
Democracy index (1=least democratic)	1.37	1.46	2.58	2.19	1.59	1.34	-0.0317

Note: These data are population-weighted means over all countries in the data set in the region.

Table A6. Explanatory Variable Means (1970, 1975, 1980, 1985, 1990, and 1995), Near East and North Africa

	1970 (1)	1975 (2)	1980 (3)	1985 (4)	1990 (5)	1995 (6)	Absolute Change 1970-95 (7)
Population with access to safe water (%)	75.6	67.8	72.2	67.9	81.9	81.5	+5.9
Female secondary enrollment rate (%)	14.1	21.4	31.1	43.3	54.6	57.9	+43.9
Ratio of female life expectancy to male life expectancy	1.048	1.046	1.044	1.043	1.043	1.044	-0.004
Per capita dietary energy supply (kilocalories)	2265	2490	2804	2955	3097	3172	+907
Per capita gross domestic product (PPP $US)	1654	1932	2397	2462	2647	2653	+999
Democracy index (1=least democratic)	2.07	2.73	3.06	3.35	3.52	2.09	+0.0219

Note: These data are population-weighted means over all countries in the data set in the region.

Table A7. Explanatory Variable Means (1970, 1975, 1980, 1985, 1990, and 1995), Latin America and the Caribbean

	1970 (1)	1975 (2)	1980 (3)	1985 (4)	1990 (5)	1995 (6)	Absolute Change 1970-95 (7)
Population with access to safe water (%)	53.6	70.0	72.3	72.3	72.9	77.3	+23.7
Female secondary enrollment rate (%)	24.7	31.8	40.0	45.9	48.8	56.5	+31.7
Ratio of female life expectancy to male life expectancy	1.075	1.083	1.094	1.096	1.098	1.098	+0.023
Per capita dietary energy supply (kilocalories)	2399	2494	2684	2653	2670	2777	+378
Per capita gross domestic product (PPP $US)	3581	4361	5085	4359	4684	4849	+1269
Democracy index (1=least democratic)	3.59	4.20	4.61	4.84	5.24	4.62	+1.032

Note: These data are population-weighted means over all countries in the data set in the region.

Table A8. Regional Groupings of Developing Countries

Region	Number of Countries	Countries
South Asia	7	Afghanistan, Bangladesh, India, Maldives, Nepal, Pakistan, Sri Lanka
Sub-Saharan Africa	45	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Congo, Congo--Democratic Republic, Cote d'Ivoire, Djibouti, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao-Tome and Principe, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
East Asia	14	Brunei, Cambodia, China, Indonesia, Korea--DP Republic, Loas, Macau, Malaysia, Mongolia, Myanmar, Philippines, South Korea, Thailand, Vietnam
Near East and North Africa	16	Algeria, Cyprus, Egypt, Iraq, Iran, Jordan, Kuwait, Lebanon, Libya, Morocco, Saudi Arabia, Syria, Tunisia, Turkey, United Arab Emirates, Yemen
Latin America and the Caribbean	28	Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Venezuela
TOTAL	110	

Note: The regional classification of countries corresponds to that employed for IMPACT model projections.

FIGURES

(Available from authors)

BOX FIGURE

(Available from authors)

APPENDIX 2
DATA AND SOURCES

(Available from authors)

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