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HOUSEHOLD AND ENVIRONMENTAL FACTORS INFLUENCING ANTHROPOMETRIC OUTCOMES IN PRESCHOOL CHILDREN IN A RURAL ETHIOPIAN COMMUNITY

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This article tests the hypothesis that anthropometrical outcomes in preschool children are a function of complex interaction between food, nutrition, health, and other physical environmental conditions within which children live and grow. A system of simultaneous equations is used to test the above hypothesis using data from an Ethiopian highland community. The results show that a child's nutritional and health status are jointly determined by dietary intake, well-being of the mother as the primary caregiver, and the state of the physical environment for agricultural production and healthy living. Among other factors, children were found to be in better health with an increase in the number of cows in their households' livestock herds. The revealed interrelatedness and complexities of cause and effect clearly dictate the

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need for a multi- or transdisciplinary approach to research and development addressing health, nutrition, sanitation, agricultural production practices, among other factors for alleviating the nutritional and health problems of children and rural households.

KEYWORDS malnutrition, anthropometrics, agroecosystem, Ethiopia, East Africa

Anthropometrical indicators—stunting (height-for-age), underweight (weight-for-age), and wasting (weight-for-height)—are generally used as a means of assessing prevalence of malnutrition among preschool children or children under 5 years of age, as they are especially vulnerable to adverse environments and respond rapidly to change. Among the three indicators, stunting is often considered the key and is used widely, as it has international references that are considered valid for most cultures and countries. In some situations, *e.g.*, Latin America and the Caribbean, underweightness has been used as a proxy for stunting as stunting and underweightness were found to be highly correlated. In that situation, a child's weight for height may appear to be normal so may not be revealed as a significant problem (WHO, 1998; Morris, 1999).

Stunting and other anthropometrical indicators do not merely reflect nutritional status of children, as a child's height or weight can be seen as a reflection of the sum of all environmental influences experienced from conception to the point of measurement (Morris, 1999). Children's health is a much more pervasive concept than children's nutrition. The WHO defines human health as "the physical, social and emotional well-being of an individual and not merely the absence of disease or infirmity." This definition implies that improving health requires addressing much more than "health" *per se* as people's health and well-being are determined by the interaction of food, nutrition, water, agricultural practices, natural resources management, income, among others (Waltner-Toews et al., 2000). For the same reason, a child's growth is a function of food and nutrition, health and diseases as well as socio-economic and ecological environment in which the child lives and grows.

It has been argued that food and health are inseparable given that food is taken for more reasons than its nutritional value (Strauss, 1990). Some authors suggest that food, health, and care need to be applied in an integrated way to plants, animals, and humans alike in a systems framework as diet and health contribute in a balanced manner to human nutritional status (Jonsson, 1993; Oshaug, 1999; Eide, 2000). Others view disease as the synergistic interaction of host, agent, and environment, and improvement in environment, *e.g.*, water supply and sanitation, as a means to improve nutritional status. Considering these interactions, diseases should be viewed as interactions of problems in human ecology (Scrimshaw, 1995).

This inseparability of interactions, however, is not adequately handled methodologically in anthropometrical models. Therefore, anthropometrical outcomes need to be explained in terms of interlinkages among these various factors rather than merely in terms of food and nutrition (Haddad, 2000; International Livestock Research Institute, 2001). The policy implications of such an approach is that in addition to food and nutrition, complementary interventions in other areas may be necessary and useful for improving human health and well-being, especially of children.

In this article, we report the anthropometrical outcomes of preschool children in a village in highland Ethiopia and test the hypothesis that these outcomes are a function of complex interaction between food and nutrition and other factors. The study area and survey methods are discussed in section 2. In section 3, the theoretical model is presented, followed by a description of the empirical model and a definition of variables used in the model in section 4. The findings from the econometric model are presented in section 5. In the final section, conclusions are drawn with a mention of their implications for policy.

THE STUDY AREA AND COLLECTION OF DATA

This study was conducted in the Yubdo Legabatu Peasant Association (the lowest level civil administrative unit) in Dendi Wereda (district), about 80 km west of Addis Ababa, the capital of Ethiopia. In rural Ethiopia, as in most of East African highland areas, poverty and malnutrition, low crop and livestock productivity, and resource degradation are major problems. Various national and international institutions have conducted research for many years aimed at generating and disseminating appropriate technologies to address these problems. Problem diagnosis and design of solutions were often approached from disciplinary and farming systems perspectives, with some degree of participatory research methods in some cases. Impacts of any generated technology have been measured mostly in terms of increased output, income, resource requirement, *e.g.*, labor by gender, capital, and credit. Often, it was implicitly assumed that the generated technologies would lead to production and availability of more and better food to solve problems of poverty and food security, and those conservation technologies would lead to reduced resource degradation.

In spite of these efforts, some of the problems have persisted and even worsened and Ethiopia is still seen as one of the poorest countries in the world. An estimated two-thirds of its population still live in absolute poverty to the extent that the productivity and useful life of its next generation is being severely compromised by a high incidence of child malnutrition and micronutrient deficiencies (ILRI, 2001). This study, a component of a larger integrated project, was motivated by the need to understand the interlinkages amongst a multitude of factors that determine health and well-being so that appropriate interventions to address the linkages could be identified.

Data for this study was collected from the Yubdo Legabatu watershed community covering an area of 2,500 hectares and a human population of about 5,000 in 845 households. The community lives on an undulating landscape with a relatively flat bottomland (henceforth called land type A)—usually located about 2,140–2,200 m above sea level (asl) with 0–7% slope; moderately sloped land in the middle (land type B) 2,200–2,400 m asl with 7–25% slope; and steep slopes (land type C)—2,400–2,800 with slopes of 25–35% at the limits of the habited top. Since the homestead of a household is located on a particular land type, most of its cultivable land is also located nearby, though it may have access to land on other land types because each household was given a share of different quality land during the land reform and land redistribution in the 1970s. However, there are significant differences in altitude and temperature, slopes and soil types, settlement patterns and housing structure, crops grown, types and extent of livestock owned, sources and quality of water available for household use, access to health and education facilities between the three land types, and these are likely to have an impact on the health and nutritional status of the inhabitants, especially children.

Of the 845 households, 270, 135, and 440 are located on land type A, B, and C, respectively. A questionnaire survey was conducted with a panel of 170 households having at least one child less than 5 years of age. Samples were drawn proportionally from each land type based on wealth status. Through participatory approaches involving focus group discussions and using a composite of several factors including oxen ownership, land ownership, and housing condition, the community identified three wealth classes—poor, medium, and rich. Ownership of oxen was found to be a more important criterion than land to determine the wealth status of a household because land is a public property, which has been distributed to farmers on a per capita basis only for use, and theoretically allocated land may be taken away anytime for redistribution. On the other hand, livestock is a private property, which can be bought and sold at will, and ownership of the number of oxen determines the ability to cultivate land well for food crop production—the basic livelihood activity.

Of the 170 selected households, a small number had more than one child less than 5 years of age making it difficult to apply a panel-type model to control for fixed and random household effects. For this reason, we randomly selected only one child from households having more than one child for data collection and analysis.[1]

Sampled households were interviewed three times corresponding with the three main seasons in Ethiopia, namely; dry season (October–February), short rains (March–May), and main rains (July–September). The nutritional surveys were based on the 24-hour recall method while those for morbidity were based on 2-week recall. For each round of nutritional survey, dietary data were collected for 3 consecutive days. Mothers and children were physically examined by qualified medical personnel for edema, pallor, exophthalmia, skin lesions, upper respiratory tract infection, etc.; their fecal samples were collected for laboratory analysis and their measurements were taken for anthropometrics. At the community level, water samples were collected from 22 of 28 identified water sources used by the community, for each of the three seasons, for bacteriological analysis.

The composition of household food intake obtained from the three rounds of nutritional surveys was computed using the Food Composition Tables for Use in Ethiopia (Ethiopian Health and Nutrition Research Institute, 1997). This provided information on household intake of energy (kilocalories), carbohydrate (grams), protein (grams), fats and oils (grams), iron (milligrams), and beta-carotene (micrograms). The water samples were incubated at 37°C for 48 and the number of coliform organisms/ml were counted.

[1] In nutrition studies, when one child is chosen from households having more than one child under the age of 5, usually the youngest child is chosen as the youngest child is assumed to be affected more by malnutrition, water problems, and environmental morbidity. However, selecting the youngest child may bias the sample toward a lower age bracket, hence, the random choice in this study.

ANTHRO© a software package from the U. S. Center for Disease Control was used for the computation of Z-scores. SPSS© version 10.0 was used for statistical analyses.

THE THEORETICAL MODEL

The analytical approach used to fit the data collected during this study is based on a well-known model in which a household maximizes a long-run utility function that depends on the health and nutrition of each member as well as goods consumed from purchase or household production, and leisure (Schultz, 1984). The basic utility function U for the ith member of household k is represented as follows:

$$U_i = U(H_i, C_i, L_i, X_{i,}, Y) \quad (1)$$

where H_i is an indicator of health and nutrition status of the *i*th member of the household, C_i is *i*th member's consumption of purchased and household produced goods, and L_i is the *i*th member's leisure, and X is a vector of exogenous variables specific to the *i*th member, and Y is a vector of variables specific to the *k*th household. The function can be maximized subject to certain constraints, *e.g.*, resource levels, production function, income levels. When the components or elements of a household model are separable, *e.g.*, decisions on production, consumption, and leisure are taken sequentially rather than simultaneously, and then the optimization problem can be solved through a system of recursive equations. If the decisions are not taken sequentially, rather simultaneously, then reduced form or structural equations may be applied to solve the optimization problem (Bouis and Haddad, 1990).

The focus of this analysis is child nutritional status, so assuming stunting (height-for-age) as the most important and widely used indicator of a child's health and nutritional status, and further assuming that the elements of the utility function are not separable, we define a child's growth production function as follows:

$$HAZ_i = f(H, M, X_{i,}, Y) \quad (2)$$

where HAZ is the height-for-age z-score [2] of the *i*th child; H is an endogenous variable representing overall health and nutritional status for household k, M is an endogenous variable representing standardized anthropometric measurement of Body Mass Index (BMI)[3] to reflect a mother's health and nutritional status in the *k*th household, Xis a vector of specific characteristics of the *i*th child, *e.g.*, child's age and gender, Y is a vector of exogenous characteristics of the *k*th household, *e.g.*, livestock endowment, place of cooking, whether housing is shared with livestock, access to hospital, quality of water for household use. In summary, Eq. 2 postulates that a child's health and well-being depends jointly and primarily on a household's well being, the status of health and nutritional status of the primary caregiver, the child's inherent characteristics, and the physical environment affecting the child's growth.

If the set of endogenous variables, namely, H and M in Eq. 2 are represented by W_i, then the demand function for each variable can be structurally represented as follows:

$$W_i = g(U_i, x_i, y) \tag{3}$$

where U_i is at least one of the above endogenous variable and $x_i$and y are relevant variables selected from X_i and Y as previously defined.

In Eq. 2 and 3, the variables have been characterized as exogenous and endogenous in recognition of the problem of estimation bias introduced into production functions when some inputs are endogenous and correlated with the error term. This simultaneity is often resolved by estimating reduced-form models with all the exogenous variables and through the use of instrumental variables or augmented regression techniques to arrive at predicted values for the endogenous inputs into the production function (Hausman, 1978; Davidson and MacKinnon, 1993). While reduced-form models are easier to estimate and appear suitable for

[2] Z-scores were based on the reference standards developed by the U.S. Center for Disease Control, the National Center for Health Services (NCHS), and the World Health Organization (WHO, 1983). Standard cut-off points and definitions have been used for malnutrition; stunting and severe stunting are defined as HAZ below −2.00 and below −3.00, respectively, underweight and severely underweight as WAZ below −2.00 and below −3.00, and wasting and severe wasting as WHZ below −2.00 and below −3.00.

[3] Body Mass Index (BMI) is a standard international nutritional assessment value obtained by dividing weight in kilograms by the square of height in meters.

determining the effects of particular interventions associated with exogenous variables in the models, they are less amenable than production functions to extrapolation beyond existing conditions (Rosenzweig and Schultz, 1988; Davidson and MacKinnon, 1993; Gujarati, 1995; Sahn and Alderman, 1997).

EMPIRICAL MODEL AND DEFINITION OF VARIABLES

Taking HAZ as the key indicator of child health and nutrition, the following structural model has been specified with the variables identified for the best fit equations to capture the direct and indirect influence of various factors on HAZ in a sequential manner:

$$CH_i = f(D_1, \ldots D_8, X_1, \ldots, X_{13}) \tag{4}$$

$$M_k = f(H^\wedge, CH^\wedge, D_6, D_7, X_1, X_6, \ldots, X_9) \tag{5}$$

$$H_k = f(M^\wedge, D_1, \ldots, D_5, X_1, X_2, X_3, X_5) \tag{6}$$

$$HAZ_i = (H^\wedge, M^\wedge, CH^\wedge, D_3, D_8, X_4, X_9, \ldots X_{13}) \tag{7}$$

where the variables are defined as below:

- CH is an index of child specific morbidity and CH^ is its predicted value.
- M is an index of mother's body mass index (MBMI), and M^ is its predicted value.
- H is a composite index of household health and nutritional status derived by combining household calorie security and morbidity, and H^ is its predicted value.
- HAZ is the height-for-age z-score of the sample child.

D_1 to D_8 and X_1 to X_{13} are, respectively, dummy and continuous independent variables defined in more detail in Table 1. Because of the

Table 1. Description of independent variables used in the econometric models.

Variables	Description
D_1	Dummy for wealth ranking of household: 1 = poor, 2 = medium, 3 = rich
D_2	Dummy for location of household: 1= Land type C, 0 = land type A and B. Types A and B were combined as values of other important independent variables did not differ significantly between these two types but difference between A or B and C were significant.
D_3	Dummy for household calorie security during the rainy season (lean period): 1 = calorie secure, 0 otherwise
D_4	Dummy for availability of hospital within land type: 1 = yes, 0 = no
D_5	Dummy for adoption of improved agricultural technology; 1 = yes, 0 = no
D_6	Dummy for cooking in living room: 1 = yes, 0 = no
D_7	Dummy for gender of head of household: 1 = male, 0 = female
D_8	Sex of child: 1= male, 0 = female
X_1	Household size in adult equivalents
X_2	Total size of cultivated land (ha)
X_3	Livestock owned by household in Tropical Livestock Units (TLU)
X_4	Number of cows owned by household
X_5	Coliform count in samples of household's main water source during the main rainy season as an indicator of water quality
X_6	Average annual intake of proteins per adult equivalent in household (g)
X_7	Index of mother's morbidity
X_8	Years of formal education of mother
X_9	Living space in dwelling house per person (m^2)
X_{10}	Daily frequency of breastfeeding the sample child
X_{11}	Age of the sample child in months
X_{12}	Number of children under 5 years of age within the household
X_{13}	Number of types of worms found in the sample child's fecal sample

structural relationship between the equations, at least one variable from a previous equation is included in the subsequent equation. Most of the variables are self-explanatory. The variables household health and nutrition index (H), mother's health index (X_7), and child-specific health index or child morbidity (CH) require additional clarification as below.

Based on the argument made earlier that nutrition and health are interlinked, diet and health status of a household was merged into a single index, H,following Oshaug(1999).It was obtained by constructing a composite index of average annual household calorie or energy security and household morbidity. To obtain the dietary intake part of the index, we classified the sample into 10 classes according to household calorie intake and then assigned numbers 1–10 to each class in ascending order of household calorie consumption. During the survey, the respondents not only listed the diseases suffered by household members but also ranked them according to how seriously they considered each of them. To construct an index for household morbidity, we used the product of number of people in each household that suffered from particular diseases, and the ranked severity of such diseases and controlled for household size. The figures obtained for the entire sample were rescaled to make 10 the highest possible morbidity score for any particular household.[4] Since disease is a negative attribute, each household's score was then subtracted from 10 to obtain a positive household morbidity index. For example, if a household had such a high incidence of diseases to have scored 8 originally, then that household's morbidity index was computed as 10 less 8 and recorded as equal to 2. Assuming the same household happened to fall within the sixth class for household calorie intake, then its health and nutrition index would be 8, resulting from the sum of a morbidity score of 2 and a calorie intake score of 6.

A morbidity index for mothers was computed using essentially the same procedure for obtaining household morbidity, as above. The only difference is that in the case of a mother's health index calculation, no attempt was made to rescale the results and constrain the maximum given that there was no need to merge this index with any other value. Similarly, a child specific morbidity index (CH) was obtained for children in the sample using the same procedure as for a mother's health index. Children who suffered less ill health during the 2-week recalls for the three rounds were expected to have higher HAZ. Since the index was reversed to make it positive, like in the case of household morbidity, it is expected that the higher the value of CH, the higher the value of HAZ will be.

The parameters of the equations were estimated by using a recursive structural model because it gave better estimates compared to reduced form models. Equation 4 was estimated by an ordinary least squares method and Eq. 5–7 were estimated by a two-stage least squares methods Predicted values of some variables were used in some equations because of the existence of endogeneity, for which appropriate tests were con-

[4]Recall that 10 is the highest possible score for household nutrition and if diet and health are to be merged on an equal basis to obtain H, then 10 also has to be the highest attainable score for household morbidity.

ducted using procedures suggested in Hausman (1978) and Davidson and Mackinnon (1993).

RESULTS OF ECONOMETRIC ANALYSIS AND DISCUSSION

The results of best fit models for Eq. 4–7 are shown in Tables 2–5, explaining variation in child morbidity, MBMI, household health and nutrition status, and stunting among children. Overall, the estimated functions explain, respectively, 39%, 36%, 36%, and 77% of the variation in the dependent variables. Lower explanatory power for the first three equations may be partly explained by a cross-section nature of the data and relatively low variation in the variables themselves.

Child-specific morbidity

Records on morbidity show that about 49% of children in the study area fell sick within the survey period. Coughing/cold (35%) and diarrhea (27%) were the most prevalent among the reported illnesses. The occurrence of such illnesses may have contributed to the observed high level of childhood malnutrition as frequent illness has a negative effect on nutritional status (see below).

Child-specific morbidity was adversely affected by farm size, wealth status of the household, land type, and worm infestation measured by the number of types of worms found in child's fecal sample (Table 2). The effects of livestock ownership, number of cows owned, breastfeeding duration, and child age are positive. All the significant variables have expected signs except for farm size and wealth status. The negative effect of wealth on the morbidity among children is unexpected but could be as a result of underreporting and/or lack of enlightenment about ill health conditions among poor parents. For example, a certain level of illness among children of poor households might have been considered normal and not worthy of reporting while the same level of ill health in a wealthier household might have been considered as serious and reported. Records on morbidity show that 49% of the children in the community fell ill during the 2-week recall period and that full immunization against all diseases is still low in the community with children in land type C being the least protected and most vulnerable to disease. This fact is reflected in the negative sign of the coefficient of land type variable.

Table 2. Summary of estimated coefficients of variables in the equation explaining the index of child's morbidity (OLS estimates).

Independent Variables	β	95% Confidence Interval	
		Lower	Upper
Farm size (X_2)	−0.736*	−1.616	0.143
Dummy for wealth status (D_1)	−1.536**	−3.107	0.035
Dummy for land type (D_2)	−2.337**	−4.708	0.033
Livestock ownership in TLU (X_3)	0.869**	0.137	1.601
Number of cows owned (X_4)	1.894**	0.1723	3.615
Coliform count in water (X_5)	0.000	−0.001	0.001
Protein intake per adult (X_6)	−0.023	−0.072	0.026
Household size (X_1)	−0.105	−0.717	0.507
Dummy for rainy season calorie security (D_3)	−1.590	−4.010	0.829
Dummy for cooking in living room (D_4)	0.453	−1.858	2.765
Mother's health index (X_7)	0.020	−0.145	0.186
Mother's education (X_8)	−0.043	−0.383	0.296
Dummy for gender of household head (D_7)	−1.120	−5.059	2.818
Frequency of breastfeeding (X_{10})	0.273**	−0.004	0.550
Dummy for child sex (D_8)	−1.068	−2.751	0.615
Child age (X_{11})	0.0733**	−0.001	0.147
Number of under 5 children in household (X_{12})	0.051	−1.309	1.412
Dummy for use of improved technology (D_5)	−1.056	−2.783	0.672
Number of worm types in fecal sample (X_{13})	−4.850***	−6.423	−3.278
R^2	0.39		

***, **, * indicate 1%, 5%, and 10% levels of significance.

The positive sign of the coefficient of age of the child suggests that children tend to outgrow illness.

Mother's BMI

The mean and standard error of MBMI was found to be 19.91(0.16. About 15% of the sample mothers were underweight (<18.5) with 5% severely underweight (<17), 80% had normal weight (18.5–25), and 5% were overweight. The presence of a significant number of adults (say ≥ 10%) with very low BMI (<17) normally indicates a need for emergency relief rather than rehabilitation or development (Morris, 1999).

Table 3, shows that MBMI significantly increased as index of child-specific morbidity index, household size, protein intake per adult, mother's

Table 3. Coefficients of factors affecting mothers' body mass index (M) estimated by two-stage least squares (2SLS) methods.

Independent Variables	β	95% Confidence Interval	
		Lower	Upper
Predicted value of household health and nutrition index (H^*)	0.303**	0.022	0.584
Predicted value of child specific morbidity (CH^*)	0.187***	0.074	0.299
Dummy for cooking in living room (D_6)	−1.126***	−1.950	−0.302
Dummy for gender of household head (D_7)	−0.206	−1.518	1.107
Household size (X_1)	0.311***	0.088	0.534
Protein intake per adult (X_6)	0.041***	0.010	0.071
Mother's health index (X_7)	0.115***	0.057	0.173
Mother's education (X_8)	−0.083	−0.208	0.042
Living space in house (X_9)	1.110***	0.406	1.185
R^2	0.36		

***, **, * indicate 1%, 5%, and 10% levels of significance.

health index, and living space per person increased. On the other hand, MBMI significantly decreased with worsening household health and nutrition status and if the household cooking is done in the living room. All of the coefficients have expected signs except child-specific morbidity index. Healthy mothers would be expected to have healthy children, but a negative relationship might occur in living environments where a child's health may be vulnerable to diseases and malnutrition, as explained by the significant effect of land type on child morbidity in the earlier equation. The positive effects of household size on MBMI may be explained by the fact that in larger households, the conventional household and agricultural works and childcare activities may be more equally shared lessening the burden on the mother. It may be noted that in the study community as elsewhere in Africa, women and children traditionally provide much of the labor for farm work including care of animals, especially cows when they are at home, water, and fuel wood collection. In larger families, these tasks may be shared so that the burden on the mother is reduced.

A mother's BMI is also negatively affected by the practice of cooking in the living room. In 60% of the sample households, the living room is shared with livestock ostensibly to warm the room and provide alternative hosts for mosquitoes. In addition to this, 73% of the households cook within the living room. The types of fuel material normally used for cooking include wood, leaves and twigs, and for most part of the rainy season cow dung cakes. None of these are high-quality fuel materials and often they are not adequately dried so they create a lot of smoke inside the house while cooking. Most of the dwelling houses are also not well ventilated due to the traditional architecture and the need to protect from cold winds in the highland environment. Consequently, the environment in the house may be detrimental for human health, especially for mothers who are responsible for cooking and also infants whose cognitive development may be adversely affected. A global study has shown that smoke in the kitchen of poor people in developing countries causes death to over 1.6 million people, mainly children and women, and that it is a major cause of acute lower respiratory infection, obstructive pulmonary disease, asthma, tuberculosis, low birth weight and infant mortality, and cataracts (Warwick and Doig, 2004).

Household health and nutrition status

Household health and nutrition index had a mean value of 13.95 and standard error of 0.24. Household health and nutrition status of the sample household significantly improved as wealth status and livestock ownership increased and the household had calorie security in the rainy season (Table 4). Wealthier households and households with a larger number of livestock would be expected to have better food security from their own production or from purchases. The nutritional and health benefits of adequate food security are well known. Households with better access to a health facility, those that adopted improved technology, and residents on land type C also had better health and nutrition status, which were plausible, but the coefficients were not statistically significant. In recent years, a number of food production technologies have been introduced to the community. The major ones are the broad bed maker (BBM) which tackles a problem of water logging experienced in flat bottomlands and enables double cropping; higher yield varieties; cereal-legume intercropping; and the use of multi-purpose trees to provide fodder, fuel, and soil fertility. Only 12% of the sample households used the BBM for vertisol management, 28% used high yielding crop varieties especially wheat, 18% planted multi-purpose trees, and 4% planted cereal/legume intercrops for increasing food and feed together. In all cases, a higher proportion of the rich households adopted these technologies. As the results

Table 4. Coefficients of factors affecting household health and nutrition status (H) estimated by two-stage least squares (2SLS) methods.

Independent Variables	β	95% Confidence Interval	
		Lower	Upper
Predicted value of MBMI (M^)	0.125	−0.295	0.544
Dummy for wealth status (D_1)	0.850**	0.042	1.658
Dummy for land type (D_2)	0.635	−0.469	1.740
Dummy for rainy season calorie security (D_3)	2.813***	1.866	3.759
Dummy for access to hospital (D_4)	0.866	−0.559	2.291
Dummy for use of improved technology (D_5)	0.209	−0.690	1.108
Household size (X_1)	−.236	−0.560	0.088
Farm size (X_2)	0.054	−0.425	0.533
Livestock ownership in TLU (X_3)	0.216**	0.011	0.420
Coliform count in water (X_5)	0.0002	−0.001	0.000
R^2	0.36		

***, **, * indicate 1%, 5%, and10% levels of significance.

indicate, households that have adopted any number of these technologies have higher household nutritional status, which would be expected, though the coefficient was not statistically significant.

Stunting (HAZ)

The mean value of HAZ was -2.18 with a standard error of 0.10. Following the World Health Organization's standards (WHO, 1985), more than 52% of children under 5 years of age were too short for their age, 22% severely so. HAZ was higher for male children and it increased significantly with better overall health and nutrition status of the household, a higher BMI of mother, a higher number of cows owned by the household, and a higher frequency of breastfeeding (Table 5). HAZ decreased with increased rainy season calorie security, living space per person, age of the child, higher number of children less than 5 years in the household, and higher number of worm types in fecal sample.

The positive impact of overall health and nutrition status of the household, MBMI, and breastfeeding duration on HAZ of infants is normally expected. The positive coefficient of cow ownership means cow ownership is beneficial to households probably through enabling relatively higher consumption of milk and its products, which leads to an

Table 5. Coefficients of factors affecting children's height-for-age z-scores (HAZ) estimated by two-stage least squares (2SLS) methods.

Independent Variables	β	95% Confidence Interval	
		Lower	Upper
Predicted value of household health and nutrition index (H^)	0.032***	0.013	0.051
Predicted value of mother's body mass index (M^)	0.070***	0.035	0.104
Predicted value of child specific morbidity (CH^)	0.006	−0.014	0.026
Dummy for rainy season calorie security (D_3)	−0.094**	−0.185	−0.004
Dummy for child sex (D_8)	0.063*	−0.010	0.136
Number of cows owned (X_4)	0.350***	0.310	0.389
Living space in house (X_9)	−0.022***	−0.137	−0.006
Frequency of breastfeeding (X_{10})	0.019***	0.006	0.033
Child age (X_{11})	−0.089***	−0.012	−0.005
Number of under 5 children in household (X_{12})	−0.203***	−0.264	−0.143
Number of worm types in facal sample (X_{13})	−0.271***	−0.377	−0.166
R^2	0.77		

***, **, * indicate 1%, 5%, and 10% levels of significance.

improvement in the nutritional status of children, and additional cash income to buy other foods not produced at home. And cow ownership may complement the effect of breastfeeding. Tangka et al. (2002) have similar findings on the impact of crossbred cows on household nutritional status in a nearby area in the Ethiopian highlands.

The negative effect of the number of children under the age of 5 years in the household on HAZ of infants seems plausible. Other things being equal, more frequent childbirth in a poor community like Ethiopia, means that infants possibly do not get as much food and nutrition as required for normal growth. Perhaps this also explains the negative effect rainy season household food security on the HAZ of the sample infant. Among the sample households , 42% were energy secure year-round but 28, 45, and 54% of, respectively, poor, medium, and rich households were energy secure. The corresponding ratios for the main rainy season, the lean period, are 34% overall and 23, 36, and 42% for poor, medium, and rich households, respectively. This means that a significant proportion of rich households were unable to provide adequate energy security to their infants. Since wealthier households also had larger family sizes with several children less than 5 years of age in each, an overall energy security might not be a guarantee for normal HAZ for all infants in such households.

The sign of the coefficient of child age indicates that children with a lower age have higher HAZ. Similar results have been obtained in previous studies (Haughton and Haughton, 1997; Haddad, 2000), in which children in Vietnam were found falling behind in growth shortly after weaning on account of a probably poorer quality of post-weaning food. It could also be seen as the cumulative effect of deprivation of nutrients, bearing in mind that HAZ is an embodiment of all previous nutritional and environmental experiences. The latter argument is plausible because where food is in inadequate supply within a household, it is customary to distribute whatever is available starting from the youngest members of the family. The stress of household food insecurity on growth would, therefore, be less on the youngest members.

Surprisingly, the average coliform count for water samples reflecting quality of water used was not significant in any of the equations. A possible explanation is that all the households have been using water of poor quality beyond normal human consumption. The average coliform count for household sources of water in the dry, small rain and main rainy season were 265, 588, and 2028 with standard errors of, respectively, 18, 32, 67. Thus all the figures are much above 161 which is the benchmark number of coliforms beyond which water is considered unfit for human consumption. This being the case, all households are exposed to water-borne diseases such that the extent to which they get infected or resist infection depends on other factors other than water quality, e.g., nutritional status or the level of household immunity to certain water-borne diseases, which were not measured in this study.

However, these results have to be interpreted with caution, bearing in mind that after evaluating the present knowledge about infant growth assessment a WHO expert committee affirmed the use of a single international reference, but recommended updating or replacing the current NCHS/WHO growth reference using a truly international reference based on carefully conducted surveys covering broad populations from several countries (de Onis and Habicht, 1997). Habicht et al. (1994) show from evidence obtained from a number of developing countries that height for well-nourished children in developing countries (outside East Asia) is close to the NCHS median, while height of poorly nourished children is not. The point being made is that where children are undernourished and the population genetically shorter than a U.S. population, then the measure may exaggerate low HAZ, in absolute but not relative terms.

SUMMARY AND CONCLUSIONS

The study reports results of study that attempted to examine and understand the links between agriculture, food consumption, culture, and physical environment on the one hand and human well-being (nutrition and health status) on the other. The importance of the analytical method applied lies in showing that the various factors affects child health and growth both directly and indirectly. For example, land type influenced child morbidity (CH*) (Table 2) , which in turn affected MBMI (Table 3) which influenced household health and nutrition status (Table 4), and then stunting of infants (Table 5). This means that an investigation into a direct relationship between stunting and the environment may not reveal any significant relationship but a relational (indirect) search on the same issue may yield results. The relationships between the environment and a child's health and growth were affected positively when the values of the following factors increased: protein intake, living space per person, land type on which household is located, wealth status of household, ownership of livestock, calorie security during the rainy season, and frequency of breastfeeding during infancy. On the other hand, cooking in the living room, higher numbers of children under the age of 5 within a household, and a high egg count of various worms in fecal sample had an overall negative effect on anthropometric outcomes in preschool children. It could be said that the endogenous and exogenous variables in the child growth (production) function reported in this article show the interplay of genetics, nutrition, health, agricultural and cultural practices, and the environment in determining household well-being as reflected in the long term by a child's height-for-age.

The results depict a rural community in Ethiopia, as is most probably the case with other rural communities in the developing world, caught in a vicious cycle of poverty, malnutrition, poor health, and environment. Specifically, following WH standards, more than 52% of children under 5 years of age are too short for their age, 22% severely so. The problem of stunting is most pronounced, in magnitude and severity, among children of poor people who in addition to being undernourished sleep on cold bare floors and are wrecked by diseases. About 15% of mothers are too light for their height: 10% are within the subnormal range and 5% with cases of extreme emaciation. The econometric analysis shows that child nutritional and health status are jointly determined by dietary intake, well-being of the primary caregiver and other household members, and the state of the physical environment for agricultural production and healthy living. Among other positive contributors, households benefited from the ownership of livestock and more so for children from households with cows.

The revealed interrelatedness and complexities of cause-and-effect demonstrated in the results clearly dictate the need for a multi- or transdisciplinary approach to research and development addressing health, nutrition, sanitation, agricultural production practices, among others for alleviating the nutritional and health problems of children and rural households. Agricultural productivity and household well-being will benefit from livestock through draft power, cash, and better food.

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