Inter-American Development Bank
Banco Interamericano de Desarrollo
Latin American Research Network
Red de Centros de Investigación
Research Network Working Paper #R-492

Undernutrition in Bolivia: Geography and Culture Matter

by

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April 2005

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Morales Anaya, Rolando.

Undernutrition in Bolivia: geography and culture matter / Rolando Morales, Ana María Aguilar, Alvaro Calzadilla.

p. cm. (Research Network Working papers ; R-492)
Includes bibliographical references.

1. Malnutrition in children—Bolivia. 2. Malnutrition in children—Bolivia—Social aspects. I. Aguilar, Ana María. II. Calzadilla, Alvaro. III. Inter-American Development Bank. Research Dept. IV. Latin American Research Network. V. Title. VI. Series.

362.19639 M575--dc22

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Abstract[1]

The prevalence of health problems and malnutrition in Bolivia is shockingly high, even relative to other developing countries. This study analyzes the association between a bidimensional measure of child health—composed of height and weight z-scores—and a set of child nutrition determinants related to physical and cultural contexts, the mother's characteristics, household assets and access to public services. The paper seeks to identify the main determinants of child health and to measure the impact of each factor related to the bidimensional indicator. A sequential strategy is adopted in order to estimate a two-equation linear model with correlated error terms. A major finding is that geographical and cultural variables are significant determinants of nutritional status, and that the role of the mother's anthropometrical characteristics is substantial. This study uses data from a Demographic and Health Survey (DHS) on over 3,000 children.

JEL classification: O12, I12, I38

Keywords: Child malnutrition, height z-score, weight z-score, SUR estimation.

[1] The authors would like to thank Jere Behrman and Emanuel Skoufias for valuable comments that helped improve an earlier version of this paper.

1. Introduction

The aim of this study is to identify the main determinants of child health in Bolivia. The authors suggest the adoption of a bidimensional anthropological measure as an indicator of child health. This measure comprises the z-scores for height and weight in children aged less than 36 months. Among the determinants of child health, the paper considers the physical and cultural context, the mother's characteristics, household assets and access to public services. The modeling strategy involves the introduction of sets of variables from each category in a sequential approach. In the initial steps, ordinary least squares (OLS) models were estimated for height and weight z-scores. Thereafter, the authors applied an algorithm for the simultaneous estimation of both equations, since they are correlated.

1.1 Undernutrition in Bolivia

Undernutrition is an acknowledged problem in Bolivia, although its complex causes are not completely understood. Data from three DHS surveys in the decade 1989-1998 reveal an overall downward trend in child undernutrition. Unfortunately, this trend has been accompanied by increases in some deprived areas. In the department of Potosí, for example, the percentage of children under two standard deviations for height-for-age increased from 33.2 percent in 1994 to 49.2 percent in 1998. Table 1 shows the movement of z-scores of height-for-age, weight-for-age and weight-for-height indicators between 1994 and 1998. It also shows the differences in nutritional status between males and females, and between urban and rural children.

Table 1. Percentage of Children with Two Standard Deviations below the Median
(Z-scores. Children between 3 and 35 months old)

Characteristics	Height-for-age		Weight-for-age		Weight-for-height	
	94	98	94	98	94	98
Male	28.2	27.1	16.5	9.9	5.5	2.1
Female	28.3	24.0	15.2	9.0	3.2	1.4
Urban	20.9	18.3	11.6	6.1	3.3	1.3
Rural	36.6	35.6	20.4	14.1	5.6	2.4

Source: Instituto Nacional de Estadística, Bolivia.

According to the 1998 Demographic and Health Survey (DHS), more than 25 percent of children are below a –2 z-score for height-for-age; 50 percent had a z-score lower than –115; and the inter-quartile range falls between –209 and –27. Few children have a height-for-age score above zero. The same survey shows that 10 percent of children are below –2 standard deviations for weight-for-age; 50 percent have a z-score lower than –53; and the inter-quartile range for this indicator is located between –128 and 28. Nearly 40 percent of children had a weight-for-age z-score above zero and in only 1.5 percent of cases was that score above two standard deviations. The data indicate that height is more compromised than weight.

1.2 Geographical and Ethnic Characteristics

Bolivia is an atypical country in at least four ways. First, it is located between the Tropic of Cancer (23.45 N latitude) and the Tropic of Capricorn (23.45 S latitude). It is thus classified as tropical from the geographical perspective, although a significant proportion of its territory is not tropical from an ecological standpoint. Second, the population is overwhelmingly concentrated in high and cold areas where agricultural productivity is low. Third, Bolivia is the only country in the Americas in which indigenous peoples (Aymaras, Quechuas and other ethnic groups) still account for most of the population. Fourth, human settlements are highly concentrated in a few cities and are dispersed in rural areas. In general, towns far from the main cities have insufficient community facilities.

Bolivia's climate varies widely, from tropical in the lowlands to glacial in the highest parts of the Andes. Temperatures depend mainly on elevation and vary little by season. Most of the northern part of the Western Andes rises to about 4,000 meters; the southern part is lower. Rainfall is scant everywhere. In the southern region, precipitation is limited and useful vegetation is sparse. Regions of the Western Andes are only lightly populated, and the south is virtually uninhabited. The *Cordillera Occidental* is a high desert with cold and windswept peaks.

The climate of the *altiplano*, which is also swept by strong, cold winds, is arid and chilly. Daily temperatures vary sharply and rainfall decreases with latitude from north to south. Sheltered valleys and basins throughout the Eastern Andes have mild temperatures, with moderate rainfall averaging 64-76 millimeters a year. Temperatures drop as elevation rises, and snowfall is possible above 2,000 meters. The eastern slopes of the Central Andes descend gradually in a complex and extensive series of flatlands and hills. Rivers, draining to the east, cut long, narrow valleys that are favorable for crops and settlements. Rich alluvial soils fill the low areas, but in some places the removal of vegetation has caused erosion.

The adverse geographical environment prompts problems of income-generation and domestic food production. Inadequate and costly transport, a result of the country's rocky terrain and scattered population, severely hinders access to basic services and to the markets of the main cities. The inhabitants of the Andes are familiar with food crises; in the *altiplano* and the valleys, recurrent cycles of drought, frost and hail affect crops and kill livestock.

2. Data

2.1 The Source of the Data

An extensive health assessment, the Bolivian DHS of 1998, is the main source of information for this paper, especially its data on the height and weight of children under three. A second source is the geographical database maintained by CIESS-Econometrica, which has useful information on conditions at the municipal level. A third source is information on municipal-level services and facilities, compiled by the Unidad de Análisis de Políticas Sociales y Económicas (UDAPE) and the Viceministerio de Participación Popular.[2]

The data on height and weight were converted to z-scores. The correlation between the height and weight z-scores is 0.66 and significant at the 0.0000 level. The effort to identify child health-related variables focused on those that might explain the gap between the reference and the observed distribution of the z-scores (for height or for weight). The large amount of information available does not cover specific nutritional programs, access to food, regional eating practices, household consumption or prices.

2.2 Determinants of Child Nutrition

Table 2 provides a statistical overview of the variables identified as the prime determinants of child nutrition. The list was drawn up following several tests to discard other variables.

[2] Estimating econometric models, the authors have shown that some variables in these sets were not significant in explaining child health.

Table 2. Descriptive Statistics of the Determinants of Child Nutrition

Variable		Obs.	Mean	Std. Dev.	Min.	Max.
Ch_age	Age in months	3,099	17.5421	10.2090	0	35
mo_lang3q	Quechua-speaking	3,099	0.1862	0.3893	0	1
ge_alt	Altitude	3,099	2263.4460	1443.6740	130	4,000
mo_talla[a]	Mother's height z-score (multiplied by 100)	3,099	-208.5063	92.7092	-411	194
mo_aedu	Mother's years of education	3,099	6.2540	4.6874	0	19
Ho_gfloor	Covered floor	3,099	0.5589	0.4966	0	1
Ho_refri	Possession of refrigerator	3,099	0.2304	0.4212	0	1
Co_drain	Public sewer system	3,099	0.2372	0.4254	0	1

[a] In this and subsequent tables and figures, "talla" refers to height.

3. Modeling Child Health

The paper assumes that households have a utility function with health, leisure and consumption as arguments, as explained by Behrman and Skoufias (2004). It adopts a bidimensional measure of child health, $<Y_1,Y_2>$,where Y_1 is the z-score for height and Y_2 is the z-score for weight for children under three. $<Y_1, Y_2>$ are related to the set of variables listed in Table 2. The latter variables belong to the groups outlined in Table 3.

Table 3. Taxonomy of the Determinants of Child Nutrition

Control Variables	Age effect	ch_age
		ch_age3
Context variables	Physical context	ge_alt
	Cultural context	Mo_lang3q
Mother's characteristics	Anthropometrics	mo_talla
	Education	mo_aedu
Household assets and access to public services	Household assets	Ho_gfloor
		ho_refri
	Access to public services	co_drain

This study pursues a sequential strategy to identify the variables related to the bidimensional measure of child health. In the first five steps of the sequence, ordinary least squares are used to estimate each equation related to height and weight z-scores. In the sixth step, the general framework is assumed under the umbrella of a simultaneous equation system with the seemingly unrelated regression (SUR) option.

4. Building the Model: Step by Step

The authors have devised six models ranging from the most simple to the most complex. Each new model contains all the variables included in the previous one. Each step in the model-building process takes variables in the same order as presented in Table 3.

4.1 Control Variables

Most studies that seek to explain the anthropometrical differences between the observed population and the reference population have found a systematic age effect. The data used for this paper detected the same effect. The value of using the age variable in the model has been pointed out by Thomas and Strauss (1992), Gibson (2002), Barooah (2002) and others, even in contexts in which the model has other childcare-related control variables. At first glance this is surprising: a specific age effect (unassociated with other variables such as the prevalence of infections at different ages) should not arise because the reference values are deflated by age effects. This could have been observed in the present authors' model, however, if not all the variables affecting child health at specific ages had been included. Hence the age effect can be interpreted as *the effect of some non-observed variables affecting child health at a specific age*.

Table 4. Model 1, Estimation with the Control Variable (Age)

Equation	Obs.	Parms	Rmse	R-sq	F-stat	P
Ch_talla	3,099	2	121.7826	0.1219	214.9400	0.0000
Ch_peso[b]	3,099	2	104.2787	0.1577	289.7200	0.0000

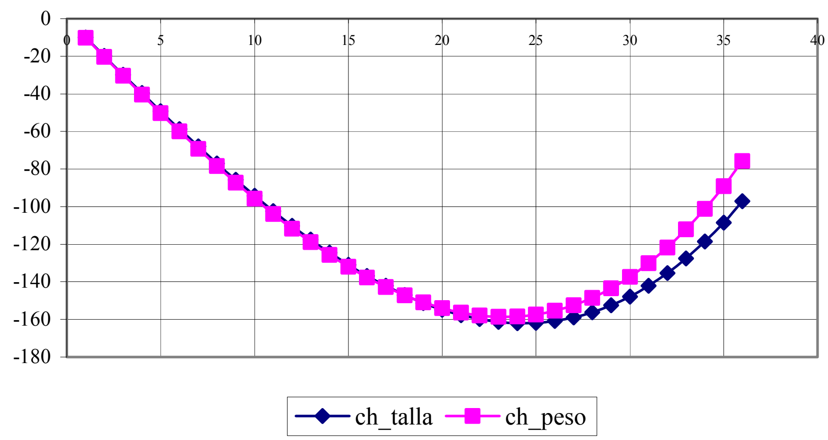
	Coef.	Std. Err.	T	P>t	[95% Conf.	Interval]
Ch_talla						
Ch_age	-10.1202	0.5439	-18.6100	0.0000	-11.1865	-9.0539
Ch_age3	0.0059	0.0004	13.5000	0.0000	0.0050	0.0067
_cons	-5.1700	5.9115	-0.8700	0.3820	-16.7586	6.4186
Ch_peso						
Ch_age	-10.6132	0.4658	-22.7900	0.0000	-11.5263	-9.7002
Ch_age3	0.0067	0.0004	17.8900	0.0000	0.0059	0.0074
_cons	64.6633	5.0618	12.7700	0.0000	54.7403	74.5862

[b] In this and subsequent tables and figures, "peso" refers to weight.

Table 4 shows the outcome of the estimation by OLS corresponding to the first step in the model-building process. Summarizing the estimations, Table 13 shows that in each stage of the model-building, the age-related coefficient estimates (for height and weight) vary little. As a descriptive measure, in the table above the R-sq coefficients show that 12.19 percent of the total variation of the z-score for height is explained by the age effect, and 15.77 percent of the variation of the z-score for weight is explained by the same variable.

The possibility of a specific gender effect can also be explored. If the gender variable is added to the previous model the coefficient estimates are not significant. The relationship between gender and nutrition has been reported as favorable for male children in the literature on Asia, while Svedberg (1990) and Yamano et al. (2003) have shown that nutrition indicators are more favorable for girls than boys in Africa. Figure 1 reveals a negative trend between birth and 20-24 months, and an improvement thereafter. As expected, weight precedes height on both the falling and rising sides of the curve.

Figure 1. The "Age" Effect on Nutrition



4.2 Context Variables

The circumstantial variables for childbearing are related to the child's cultural and geographical context and the mother's anthropometrical characteristics.

4.2.1 Cultural Context

Language is one way of identifying culture. In Bolivia there are two main ancestral cultures, Quechua and Aymara, as well as the imported Spanish culture. There are others, but their numerical significance is not comparable with the three mentioned. In many cases, good childcare practices are acquired through non-formal education. Culture is therefore significant in this regard, and verbal communication is very important.

In Bolivia the "institutional" language is almost solely Spanish.[3] Women who speak only indigenous languages tend to enfold themselves in the family and seek help from older relatives, who do not always provide the best advice. Table 5 shows the mean of the z-score for height and weight according to the mother's language. Note the difference between the anthropometrical indicators in each of these cultures. Later, this paper examines whether there are significant socioeconomic discrepancies behind these differences.

Table 5. Height and Weight Z-Scores (Means), by Mother's Language

Language	ch_talla	ch_peso
Spanish	-103.5395	-38.8423
Aymara	-156.4843	-58.4465
Quechua	-175.1369	-87.6343

A first regression exercise includes the Aymara and Quechua languages as dummy variables (assigning Spanish the function of control variable). Both variables seemed statistically significant, but the Aymara coefficients become less significant when other, mother-related variables were introduced, especially the mother's education. Table 6 helps clarify this matter.

Table 6. Mother's Height and Years of Schooling, by Language

Language	Height	mo_aedu
Spanish	-203	7.41
Aymara	-227	3.51
Quechua	-242	2.57

Relative to their Spanish-speaking or Aymara peers, Quechua mothers exhibit the worst child health indicators, and these differences are related to the mother's educational level. When anthropometrical characteristics and the mother's education are included in the regression, the Aymara effect loses its significance. The Quechua effect, by contrast, is always significant, even in the presence of other variables.

[3] Most health workers deal with and guide mothers in Spanish, which for non Spanish-speaking mothers is a significant disadvantage that is hard to overcome.

It is not clear why Quechua children have poorer nutritional indicators than other children.[4] Genetics, as is generally accepted, has a minimal influence on the nutritional status on children under three.[5] Differences in nutritional indicators, therefore, are related to dissimilar cultural patterns of childcare. Several studies have pointed out that Quechua-speaking families (after controlling for other factors) exhibit poorer nutritional indicators than others, but none has sought to determine why these differences obtain.

In Table 7, the coefficient estimate for this variable (*mo_langq3*) is high in both equations, but it falls when other variables are introduced into the model (see Table 13). Inclusion of this variable helps explain the height and weight z-scores of 17.15 and 19.00 percent, respectively.

Table 7. Model 2, Adding Quechua Culture

Equation	Obs.	Parms	RMSE	R-sq	F-Stat	P
ch_talla	3,099	3	118.3122	0.1715	213.5800	0.0000
ch_peso	3,099	3	102.2734	0.1900	242.0000	0.0000

	Coef.	Std. Err.	T	P>t	[95% Conf.	Interval]
ch_talla						
ch_age	-10.3504	0.5287	-19.5800	0.0000	-11.3869	-9.3140
ch_age3	0.0060	0.0004	14.1700	0.0000	0.0052	0.0068
mo_lang3q	-74.3774	5.4640	-13.6100	0.0000	-85.0888	-63.6660
_cons	11.4259	5.8710	1.9500	0.0520	-0.0834	22.9351
ch_peso						
ch_age	-10.7757	0.4570	-23.5800	0.0000	-11.6717	-9.8798
ch_age3	0.0067	0.0004	18.4600	0.0000	0.0060	0.0075
mo_lang3q	-52.5110	4.7233	-11.1200	0.0000	-61.7704	-43.2517
_cons	76.3801	5.0751	15.0500	0.0000	66.4311	86.3291

4.2.2 Physical Context

It is widely accepted that geographical variables are among the most important factors underlying Bolivian development, but the following matters remain unclear: (i) the significance

[4] It is not clear, for example, why Aymara children have better nutritional indicators than Quechua children if both have the same living conditions. This observation was made by Miller (1985) and Greksa (1984). Marini and Gragnoli (2003) found that indigenous children have poorer indicators than Hispanic children when all other factors are controlled, but they did not seek an explanation. More research is needed to explain why indigenous children have poor nutritional indicators.

[5] See, for example, Habicht et al. (1974).

of such variables in Bolivia's development process, especially in health and nutrition, relative to economic and political variables; (ii) the link between geography and patterns of human settlement; (iii) the extent to which geographic variables explain nutritional disparities; and (iv) whether regional nutritional disparities will diminish in the future.

People whose livelihoods depend on agriculture are influenced by the annual fluctuations in rainfall and temperature that prevail in many rural areas without irrigation facilities. Climatic seasonality affects the growing and harvesting of crops, as well as the scheduling and intensity of both agricultural and off-farm labor.

Some studies on the high prevalence of undernutrition in Bolivia have proposed that factors such as high altitude, hypoxia and/or genetics have a negative influence on children's growth.[6] This hypothesis is founded on anthropometrical surveys indicating that, at high altitude, growth is slower than international standards even when enough nutrients are available. There is currently a debate as to whether high altitude should be accepted as an explanation for undernutrition. Several studies have shown that good childcare practices can lead to normal growth and development patterns in any child, irrespective of altitude, although the model used here suggests that altitude does affect nutrition, controlling for all other factors.

A well-documented study of high altitude (Heath and Reid, 1995) points out that barometric pressure, oxygen concentration and humidity decline with rising altitude, while cold intensifies and solar, ultraviolet and cosmic radiation increase. The complex process of adaptation to these conditions involves most systems of the body. Basal metabolism has to increase with altitude and cold, and iron and energy requirements are higher. Other conditions, such as anorexia, hypophagia, and high-protein catabolism, only appear in circumstances of acute altitude changes.

The term "high altitude" lacks a precise scientific definition. The present authors have defined it as 3,000 meters or higher, based on the symptoms exhibited by lowlanders when they ascend mountains. In describing the acclimatization and/or adaptation processes undergone by millions of people throughout the world, this paper underlines the complexity of the matter. A variety of factors, apart from hypobaric hypoxia, influence the lives of highlanders, and the most significant include genetic background, diet and prevalent chronic infections.

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[6] Frisancho and Beker (1970); and Greksa (1984, 1986). Also see Miller (2001).

An example is the diversity of results in growth and development studies of children living at high altitude worldwide. Most of these studies indicate the role of altitude relative to other variables, such as well-being and socioeconomic conditions, in defining young children's growth patterns. Higher altitude might delay the age of menarche and lower the fertility rate, both of which are important factors in preventing early pregnancy and increasing inter-gestational intervals. The weight of high-altitude newborns, however, is described as below that of children born at lower altitudes, a result of the reduction of maternal oxygen transport, fetal hypoxia and limited fetal growth.

Table 8. Model 3, Adding Altitude

Equation	Obs.	Parms	RMSE	R-sq	F-Stat	P
ch_talla	3,099	4	116.1291	0.2021	195.8800	0.0000
ch_peso	3,099	4	101.8138	0.1975	190.3900	0.0000

	Coef.	Std. Err.	T	P>t	[95% Conf.	Interval]
ch_talla						
ch_age	-10.3216	0.5190	-19.8900	0.0000	-11.3389	-9.3042
ch_age3	0.0059	0.0004	14.3300	0.0000	0.0051	0.0068
mo_lang3q	-62.0745	5.4810	-11.3300	0.0000	-72.8192	-51.3297
ge_alt	-0.0161	0.0015	-10.8800	0.0000	-0.0190	-0.0132
_cons	45.4718	6.5569	6.9300	0.0000	32.6179	58.3257
ch_peso						
ch_age	-10.7632	0.4550	-23.6600	0.0000	-11.6551	-9.8713
ch_age3	0.0067	0.0004	18.4900	0.0000	0.0060	0.0074
mo_lang3q	-47.1739	4.8054	-9.8200	0.0000	-56.5941	-37.7536
ge_alt	-0.0070	0.0013	-5.3900	0.0000	-0.0095	-0.0044
_cons	91.1497	5.7487	15.8600	0.0000	79.8804	102.4191

In the present authors' model-building process, altitude has a specific effect on children's height and weight at all stages, and its coefficient estimates vary only slightly when other variables are introduced (see Table 13). As a descriptive measure, in Table 8 the R-sq coefficients show that, adding altitude, 20.21 percent of the total variation of the z-score for height and 19.75 percent of the variation of the z-score for weight are explained by the model's independent variables. All the coefficients are significant at a 0.0000 level.

4.3 The Mother's Characteristics

4.3.1 Maternal Anthropometrics

Some authors (Barrera, 1990) have suggested that the contribution of maternal education to child health might be significantly overestimated if maternal endowments such as height and body mass index are not controlled. To some extent, maternal height represents the mother's nutritional history and her living conditions since birth. Small maternal size reflects a history of deprivation that is directly related to small offspring, and its impact extends beyond the outcome of pregnancy. It probably leads to stunting in childhood and to slow learning in adolescence, and later affects the woman's capacity for daily work. The data show that a significant proportion of Bolivian women are short; half of them are below –2 standard deviations for height. (Recall that Table 5 shows this is particularly true of Quechuan women).

Table 9. Model 4, Adding Mother's Height

Equation	Obs.	Parms	RMSE	R-sq	F-Stat	P
Ch_talla	3,099	5	111.9720	0.2584	215.5600	0.0000
Ch_peso	3,099	5	100.0292	0.2257	180.2700	0.0000

	Coef.	Std. Err.	T	P>t	[95% Conf.	Interval]
Ch_height						
Ch_age	-10.0447	0.5007	-20.0600	0.0000	-11.0262	-9.0631
Ch_age3	0.0057	0.0004	14.1500	0.0000	0.0049	0.0065
mo_lang3q	-50.4320	5.3391	-9.4500	0.0000	-60.8985	-39.9654
ge_alt	-0.0127	0.0014	-8.7800	0.0000	-0.0155	-0.0098
mo_talla	0.3424	0.0223	15.3300	0.0000	0.2986	0.3861
_cons	105.1503	7.4247	14.1600	0.0000	90.5953	119.7052
ch_weight						
ch_age	-10.5922	0.4473	-23.6800	0.0000	-11.4690	-9.7153
ch_age3	0.0066	0.0004	18.3200	0.0000	0.0059	0.0073
mo_lang3q	-39.9813	4.7697	-8.3800	0.0000	-49.3315	-30.6311
ge_alt	-0.0049	0.0013	-3.7700	0.0000	-0.0074	-0.0023
mo_talla	0.2115	0.0200	10.6000	0.0000	0.1724	0.2506
_cons	128.0182	6.6328	19.3000	0.0000	115.0157	141.0208

Table 9 shows the estimates of the new model with the inclusion of the maternal height z-score. While all the coefficients are statistically significant, the maternal language coefficient declines in absolute value and the R-sq coefficients increase substantially. Some 25.84 percent of the total variation of the z-score for height, and 22.57 percent of the variation of the z-score for weight, are now explained by the variables of the model. The coefficients of age and altitude change little.

In an effort to understand the nutrition effect of being Aymara-speaking, the authors introduce the variable mo_aimara into the regression (after adding the mother's height), and obtain the following levels of significance:

Equation	Coef.	Std.	Err.	T	P>t
Ch_height	mo_aimara	-34.4483	9.4008	-3.6600	0.0000
Ch_weight	mo_aimara	-13.0373	8.3030	-1.5700	**0.1160**

Note. Non-significant parameters in bold.

As this table shows, Aymara-speaking is significant in the first equation but not in the second. The overall test for both equations provides the following outcome:

[ch_talla]mo_aimara = 0
[ch_peso]mo_aimara = 0

F(2, 6182) = 7.95
Prob > F = 0.0004

In this step, therefore, *mo_aimara* is still significant. The introduction of variables related to the mother's education, however, causes *mo_aimara* to lose significance (see below).

4.3.2 The Mother's Education

Formal education enables women to take fuller advantage of the environment.[7] It is also a source of empowerment and offers the prospect of higher income. The childcare effects may start with communication in Spanish, making better use of facilities, and having a greater understanding of any guidance given to improve childcare. A literate mother may take more advantage of health institutions' mass communication initiatives (through posters, leaflets and so on) to convey nutritional information. Maternal knowledge of nutrition is an important determinant of a child's nutritional status (Webb and Block, 2003). In Bolivia, according to the DHS, a third of mothers have fewer than three years of schooling, and less than 10 percent have completed secondary education.

[7] See, for example, Barrera (1990); Behrman (2000); and Thomas (1994).

Mother's education is a recognized determinant of a child's nutritional status, as acknowledged in a significant body of literature (Behrman and Wolfe, 1984; Thomas, Strauss and Henriques, 1991; Gibson, 2001; Barooah, 2002[8]). Nonetheless, there is some disagreement about its importance relative to other determinants. Haddad et al. (2002), using DHS data for 16 countries, surprisingly found that parental education is a positive and significant determinant of the weight-for-age indicator in only something more than a third of cases. This finding runs counter to the conventional wisdom, according to which maternal education ranks first among the determinants of a child's nutritional status.

Table 10. Model 5, Adding Mother's Education

Equation	Obs.	Parms	RMSE	R-sq	F-Stat	P
ch_talla	3.099	6	109.5374	0.2905	211.04	0.0000
ch_peso	3.099	6	98.7434	0.2457	167.84	0.0000

	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
ch_talla						
ch_age	-10.0145	0.4898	-20.4500	0.0000	-10.9747	-9.0543
ch_age3	0.0057	0.0004	14.4700	0.0000	0.0049	0.0064
mo_lang3q	-26.2626	5.6082	-4.6800	0.0000	-37.2567	-15.2685
ge_alt	-0.0147	0.0014	-10.3500	0.0000	-0.0175	-0.0119
mo_talla	0.2840	0.0224	12.6800	0.0000	0.2400	0.3279
mo_aedu	5.5185	0.4664	11.8300	0.0000	4.6042	6.4327
_cons	58.0464	8.2826	7.0100	0.0000	41.8097	74.2831
ch_peso						
ch_age	-10.5713	0.4416	-23.9400	0.0000	-11.4369	-9.7057
ch_age3	0.0066	0.0004	18.5600	0.0000	0.0059	0.0072
mo_lang3q	-23.2999	5.0556	-4.6100	0.0000	-33.2106	-13.3892
ge_alt	-0.0063	0.0013	-4.9000	0.0000	-0.0088	-0.0038
mo_talla	0.1712	0.0202	8.4800	0.0000	0.1316	0.2108
mo_aedu	3.8088	0.4204	9.0600	0.0000	2.9846	4.6329
_cons	95.5078	7.4664	12.7900	0.0000	80.8711	110.1445

Thomas (1994), using household surveys from the United States, Brazil and Ghana, has shown that a mother's education has a greater effect on her daughter's height, while a father's education has a greater impact on his son's height. The Bolivian DHS study does not support these findings. Table 10 shows the estimation outcome of the new model with the addition of maternal education. All the coefficients are statistically significant at 0.0000 and the R-sq

[8] Barooah (2002), in line with Basu and Foster (1998), uses a broader concept of literacy and indicates the importance of a literate person's influence on an illiterate mother when they have a good degree of interaction.

coefficients increase significantly. Some 29.05 percent of the total variation of the z-score for height and 24.57 percent of the variation of the z-score for weight are now explained by the variables of the model.

Tables 9 and 10 show that the age and altitude coefficients change only slightly when the new variables are added, but the Quechua language coefficient changes substantially. If the Aymara language variable (*mo_aimara*) is added to the model, all the other variables are still significant. The significance level for this variable is as follows:

Equation		**Coef**	**Std. Err.**	**T**	**P>t**
Ch_height	mo_aimara	-11.4211	9.4485	-1.2100	0.2270
Ch_weight	mo_aimara	2.8020	8.5192	0.3300	0.7420

The Aymara language is not significant in any of the equations. This is important because it shows that the low nutritional levels evident in the Aymara population are attributable to the mother's lack of education, and that being Aymara has no particular effect. Being Quechua, by contrast, is still significant in explaining undernutrition.

4.4 Household Assets and Access to Public Services

As mentioned earlier, the DHS survey lacks information on household expenditure and assets. In the absence of income and assets data, whether the dwelling's floor is covered or not is an acceptable indicator of permanent household income.[9] The presence of a refrigerator is also linked to income.

In many studies, access to running water is an important factor in child health. In the present study, access to sewerage is statistically more important than access to running water. Access to sewerage, nonetheless, almost always includes access to running water. The matter is illustrated in Table 11.

[9] Mecovi data for 2000, for example, show that 62 percent of those in houses with a covered floor are not extremely poor, whereas 62 per cent of those in houses with an uncovered floor are extremely poor.

Table 11. Relation between Access to Running Water and Access to Public Sewerage

Running water	With sewerage No	Yes	Total
No	42.6	0.9	43.5
Yes	33.7	22.8	56.5
Total	76.3	23.7	100.0

Table 12 shows the estimation of the model when the variables *ho_floor*, *ho_refri* and *co_drain* are included. The new variables are dichotomous. The difference in the child height z-score between a household with a covered floor and a refrigerator and one that lacks these features is 76.35. The difference in the weight z-score is 61.21. Hence these variables are important explanatory factors of child health.

Table 12. Model 6, Adding Household Assets and Public Services, SUR Estimates

Equation	Obs.	Parms	RMSE	R-sq	F-Stat	P
ch_talla	3.099	9	107.2581	0.3182	1446.45	0.0000
ch_peso	3.099	9	97.1227	0.2686	1138.01	0.0000

	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
ch_talla						
ch_age	-10.2202	0.4800	-21.2900	0.0000	-11.1609	-9.2794
ch_age3	0.0057	0.0004	14.9800	0.0000	0.0050	0.0065
mo_lang3q	-17.9952	5.6200	-3.2000	0.0010	-29.0102	-6.9802
ge_alt	-0.0160	0.0015	-10.6400	0.0000	-0.0189	-0.0130
mo_talla	0.2651	0.0221	12.0200	0.0000	0.2219	0.3084
mo_aedu	2.4791	0.5350	4.6300	0.0000	1.4305	3.5277
ho_gfloor	27.9398	4.7720	5.8500	0.0000	18.5868	37.2927
ho_refri	34.0146	5.6262	6.0500	0.0000	22.9874	45.0417
co_drain	14.3960	5.5602	2.5900	0.0100	3.4982	25.2939
_cons	50.3342	8.2420	6.1100	0.0000	34.1802	66.4883
ch_peso						
ch_age	-10.7323	0.4346	-24.6900	0.0000	-11.5841	-9.8804
ch_age3	0.0066	0.0003	19.0700	0.0000	0.0059	0.0073
mo_lang3q	-15.4458	5.0889	-3.0400	0.0020	-25.4199	-5.4716
ge_alt	-0.0082	0.0014	-6.0100	0.0000	-0.0108	-0.0055
mo_talla	0.1587	0.0200	7.9400	0.0000	0.1195	0.1978
mo_aedu	1.3987	0.4845	2.8900	0.0040	0.4491	2.3482
ho_gfloor	24.5353	4.3210	5.6800	0.0000	16.0662	33.0044
ho_refri	19.3884	5.0945	3.8100	0.0000	9.4033	29.3735
co_drain	17.2814	5.0348	3.4300	0.0010	7.4134	27.1495
_cons	90.5642	7.4632	12.1300	0.0000	75.9366	105.1918

Given that the data on height and weight relate to the same children, a correlation can be expected between the equations explaining both variables. Nevertheless, application of an SUR algorithm for the simultaneous estimation of both equations provides estimators that are very similar to those of the OLS estimation. Table 12 gives the estimation results of the new and final model with the SUR assumption. The correlation between residuals is 0.5403 and is significant at the 0.0000 level. As the table reveals, all the coefficients are statistically significant at 0.01 (at least), the R-sq coefficients have increased again, and some 31.82 percent of the total variation of the z-score for height and 26.86 percent of the variation of the z-score for weight are explained by the variables of the model.

The hypothesis that some of the coefficients in both equations are nil can be rejected. This is important because it shows that the model's variables are meaningful to children's health.

4.5 Summary of Different Models

In the six models, all the coefficients are significant at the 0.01 level. Table 13 shows that: (i) the coefficient estimates of age and age3 in both equations vary slightly when new variables are introduced into the model. This suggests that these variables have a strong linear independence from the others; (ii) a similar observation can be made for altitude; (iii) the introduction of the mother's height, skills and assets changes the estimation of the cultural variable *mo_lang3q*, but the scale of the change is not enough to diminish significance (this is not the case with Aymara culture); (iv) the importance of maternal height diminishes when skills are taken into account; and (v) the importance of the mother's education decreases when assets and residence are taken into account.

There is a surprising result in Table 14: the coefficients of six of the nine variables in the model are not statistically different in the two equations. This means, for example, that belonging to Quechuan culture has a similar effect on the height z-score as on the weight z-score. That is also the case for the mother's education, for the presence of a covered floor and for access to public services. As to the variables that do not have similar effects, maternal height is more important for children's height than for their weight, and altitude influences height more than weight.

Table 13. Estimation Summary

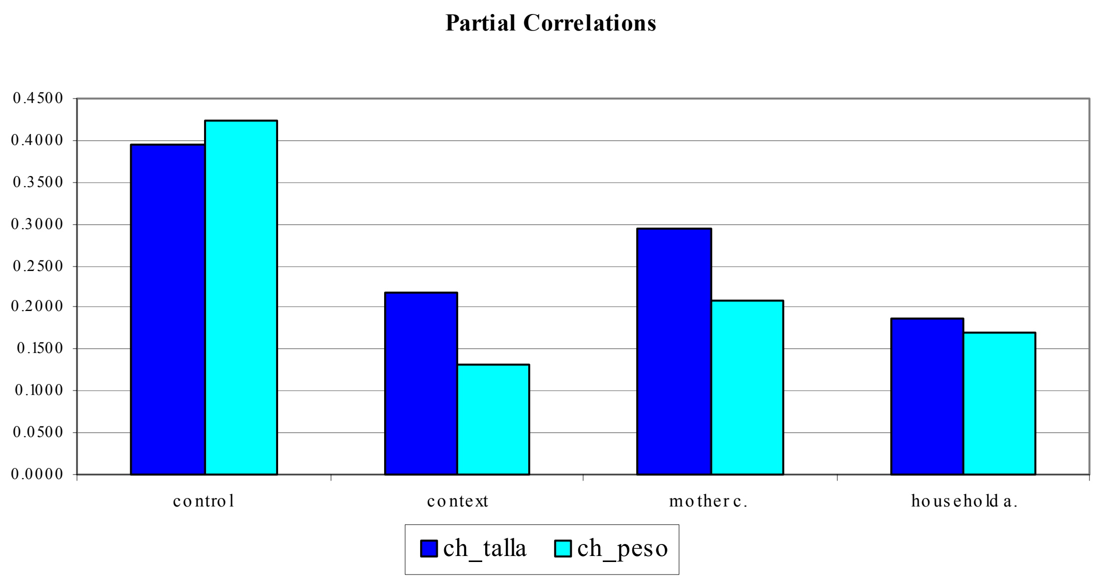
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
R- sq	Control variable (age)	Quechua	Quechua and altitude	Mother's height z-score	Mother's education	Assets and public services, SUR model
ch_talla	0.1219	0.1715	0.2021	0.2584	0.2905	0.3182
ch_peso	0.1577	0.1900	0.1975	0.2257	0.2457	0.2686
ch_talla						
ch_age	-10.1202	-10.3504	-10.3216	-10.0447	-10.0145	-10.2202
ch_age3	0.0059	0.0060	0.0059	0.0057	0.0057	0.0057
mo_lang3q		-74.3774	-62.0745	-50.4320	-26.2626	-17.9952
ge_alt			-0.0161	-0.0127	-0.0147	-0.0160
mo_talla				0.3424	0.2840	0.2651
mo_aedu					5.5185	2.4791
ho_gfloor						27.9398
ho_refri						34.0146
co_drain						14.3960
_cons	-5.1700	11.4259	45.4718	105.1503	58.0464	50.3342
ch_peso						
ch_age	-10.6132	-10.7757	-10.7632	-10.5922	-10.5713	-10.7323
ch_age3	0.0067	0.0067	0.0067	0.0066	0.0066	0.0066
mo_lang3q		-52.5110	-47.1739	-39.9813	-23.2999	-15.4458
ge_alt			-0.0070	-0.0049	-0.0063	-0.0082
mo_talla				0.2115	0.1712	0.1587
mo_aedu					3.8088	1.3987
ho_gfloor						24.5353
ho_refri						19.3884
co_drain						17.2814
_cons	64.6633	76.3801	91.1497	128.0182	95.5078	90.5642

Table 14. Tests of Equality of the Coefficients in Both Equations

	Are the estimates equal? Chi(1)	Prob>chi(1)	ch_talla-ch_peso =0
ch_age	1.35	0.2448	Yes
ch_age3	6.21	0.0127	Yes
mo_lang3q	0.24	0.6209	Yes
ge_alt	32.16	0.0000	
mo_talla	27.68	0.0000	
mo_aedu	4.85	0.0277	Yes
ho_gfloor	0.60	0.4367	Yes
ho_refri	8.03	0.0046	
co_drain	0.32	0.5716	Yes
_cons	28.31	0.0000	

Figure 2 shows the partial correlation of health indicators for each set of variables in Table 3, controlling for the other sets. All partial correlations are significant at the 0.0000 level.

Figure 2. Partial Correlations with Height and Weight Z-Scores, Controlling for All Other Variables



5. Conclusion

This study confirms that the number of undersized and underweight children in Bolivia remains high. To explain why, the authors built a set of regression models. The factors related to child health were classified as control variables, context variables, the mother's characteristics, household assets and access to public services. Equations for height and weight z-scores were estimated sequentially, including the following variables at subsequent steps: (i) children's age; (ii) altitude and the mother's language; (iii) the mother's height and education; and (iv) household assets: a covered floor, a refrigerator and drainage through a public sewer. To complete the analysis, two simultaneous equation models were estimated. The model considered here belongs to the family of SUR models, with two equations: Y1 to explain height scores, and Y2 to explain weight scores.

The main finding of the study is that altitude and Quechua culture influence child health. There is a need for further research on the physical process behind the factors affecting child nutrition.

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