UNDERSTANDING STUNTING IN PERUVIAN CHILDREN: A MULTILEVEL ANALYSIS

By

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THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN DEVELOPMENT ECONOMICS

UNIVERSITY OF NORTHERN BRITISH COLUMBIA

May, 2015

Abstract

This thesis applies the Chronic Undernutrition Framework by Tufts University (2001) in order to analyze the determinants of chronic malnutrition, or more specifically stunting, in Peru. Using cross-sectional data for children aged 6-59 months old taken from the Peruvian Demographic and Health Survey for 2009-2012, I apply a multilevel analysis approach to test the effect of individual, household and community factors for stunting in two groups of children from ages 06 to 24 months and 25 to 59 months old. The findings of this study are consistent with the literature, and support the multisectorial approach to decrease stunting. The results indicate considerable effects at each level (individual, household and community). Significant determinants at the individual level are age (for children 6-24 months old), gender, low birth weight and diarrheal disease. At the household level, wealth and mother's education are clearly associated with child growth. Access to healthcare services and antenatal care and living in mountains areas are significant factors at the community or environmental level. Also, the Articulated Nutrition Program implemented by the Peruvian government since 2008 appears to have favourable impact on children between the ages of 25 and 59 months old.

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Abbreviations

ANP	Articulated Nutrition Program
CIP	Comprehensive Implementation Plan
CM	Chronic Malnutrition
CU	Chronic Undernutrition
CDC	Centers for Disease Control and Prevention
DHS	Demographic and Health Survey
HAZ	Height for age z-score
INEI	National Institute of Statistics and Informatics of Peru
MDG	Millennium Development Goal
MEF	Ministry of Economy and Finance of Peru
MIDIS	Ministry of Development and Social Inclusion of Peru
MMPV	Ministry of Woman and Vulnerable Population
NCHS	National Center for Health Statistics
NPTAI	National Plan to Take Action for the Infancy and Adolescence
OLS	Ordinary Least Square
PSU	Primary Sample Unit
BfR	Budget for Results
SD	Standard deviation
SPSS	Statistical Package for the Social Science
STATA	Data Analysis and Statistical Software

UNICEF	The United Nations Children's Fund
UNSSCN	United Nations System Standing Committee on Nutrition
WHO	World Health Organization

Acknowledgment and Dedication

I would like to thank my supervisor Dr. Jalil Safaei, for his support throughout this project. This thesis would not have been written without his guidance and encouragement. I also would like to thank my committee members, Dr. Fiona MacPhail and Dr. Mamdouh Shubair for taking an interest in my investigation and for their useful and invaluable comments.

I owe a great thank you to my friend Dr. Luis Cordero, who, when I thought I was not able to understand how to apply a multilevel analysis, told me I was. His knowledge, experience, guidance and encouragement throughout my research brought me to this point.

I want to thank my parents, Luis and Carmen, and my sisters, Paola and Carmen, for their unconditional support, love and encouragement. Thank you for always believing in me. Gracias a mis padres, Luis y Carmen, a mis hermanas, Paola y Carmen, por su apoyo incondicional, amor y por creer en mí siempre.

Chapter 1: Introduction

1.1 Background

The importance of child nutrition on development outcomes has gained increased international awareness over the years. Strong evidence shows that inadequate nutritional status during pregnancy and in the first two years of life leads to lower human capital endowments, negatively affecting physical strength and cognitive ability in adults. This contributes directly to a reduction of individuals earnings potential and damages national economic growth (World Bank, 2007; Save the Children, 2013).

Save the Children (2013) based on a study with a panel data of 3 000 children in four countries (Ethiopia, India, Peru and Vietnam) born between the years 1994-1995 and 2000-2001, estimated that the global economic impact of child malnutrition at 125 billion dollars a year by the time today's children reach working age in 2030. Specifically, chronically malnourished children are significantly less able to read, write a simple sentence, or perform basic arithmetic, and their average adult earnings will be 20% less than healthy children.

Therefore, child undernutrition[1] is a global problem that has been addressed by different developing countries as well as different aid organizations. It is a major Millennium

[1] The literature uses the terms: undernutrition and malnutrition interchangeably. However, it must be taken into consideration that they have different meanings. According to Prakash (2006) "Malnutrition refers to all deviations from adequate and optimal and nutritional status, including energy undernutrition and over-nutrition (obesity is a form of malnutrition). The term 'undernutrition' is used to "refer to generally poor nutritional status" (Shetty, 2006, p. 526). In this sense malnutrition implies undernutrition but also over-nutrition. For the purpose of this thesis I will use the term "undernutrition".

Development Goal (MDG)[2] target which is a key indicator for measuring progress towards MDG1: Reduce poverty, hunger and undernutrition, and a critical input factor for achieving MDG4: reduce child mortality, and MDG5: Improve maternal health.

Undernutrition is defined by UNICEF (2003) as the outcome of insufficient food intake and repeated infectious diseases. However, their manifestations on children health status will vary depending on severity, duration and age (Wright & Garcia, 2012). In this sense, undernutrition can be separated in two groups acute and chronic, most often demonstrated by wasting and stunting, respectively (Reinhardt & Fanzo, 2014), or by underweight if it is a combination of both types (UNICEF, 2013)[3].

Acute undernutrition (AU) is an effect of an immediate problem such as sudden catastrophes, seasonal depressions/shortages, highly infection-disease environments. Whereas, chronic undernutrition (CU) is more closely associated with latent poverty, chronic food insecurity, poor feeding practices, and prolonged health problem (Bergeron & Castleman, 2012; Reinhardt & Fanzo, 2014).

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[2] At the Millennium Summit in September 2000 the largest gathering of world leaders in history adopted the UN Millennium Declaration, committing their nations to a new global partnership to reduce extreme poverty and setting out a series of time-bound targets, with a deadline of 2015 that have become known as the Millennium Development Goals. There are 8 Millennium Development Goals (MDGs); MDG1: Reduce poverty, hunger and undernutrition; MDG2: Achieve universal primary education; MDG3: Promote gender equality and empower women; MDG4: Reduce child mortality; MDG5: Improve maternal health; MDG6: Combat diseases (HIV/AIDS, malaria); MDG7: Ensure environmental sustainability and MDG8: Develop a global partnership for development. (United Nations, 2014)

[3] Stunting, underweight, wasting and severe acute undernutrition are defined as follows: Stunting "reflects chronic undernutrition during the most critical periods of growth and development in early life" and it is measured on the height for age of the children aged to 0 to 59 months; underweight "is a composite form of undernutrition that includes elements of stunting and wasting" here the indicator takes into account the weight for age of children aged 0 to 59 months old, wasting "reflects acute undernutrition, and both wasting and severe acute undernutrition consider the weight for height", but for children aged 0 to 59 months and 6 to 59 months, respectively (UNICEF, 2013, p. 7)

Chronic Undernutrition "is defined as a form of growth failure that causes both physical and cognitive delays in growth and development". Stunting is the indicator used as a proxy of CU, and it is also known as linear growth failure, defined "as the inability to attain potential height for a particular age" (Reinhardt & Fanzo, 2014, p. 1). The causes of CU are multidimensional, as are the consequences, which can be both short-term and long-term

Chronic Undernutrition is a priority for the Peruvian Government. It is a main topic in all the policies oriented to early infancy. It is one of the main indicators of the National Plan to Take Action for the Infancy and Adolescence for the year 2021 (MMPV, 2012). It is also one of the main outcomes of the Budget for Results (BfR) policy BFR's policy was implemented since 2007 and it is ruled by the General Law of Budgeting (MEF, 2011).

Regardless of the many efforts and strategies of the Peruvian Government, CU is still a major problem in Peru. According to the Demographic and Family Health Survey (DFHS) for the years 2000-2012, stunting in children under five years old began to decline in 2009 after a period of stagnation from 2000 to 2007, where it stayed at a level close to 30%. In 2012, the rate was 18.1%, a significant decline from a rate of 28.0% in 2005. In rural areas the drop was even more significant as it went from 47.1% to 31.9%, a drop of 15.2 percentage points. Despite these improvements, the rates of stunting still remain high in the rural areas and in some geographic regions of Peru (INEI, 2014).

The high rates of stunting in Peru shows a need for the Peruvian government to take on the major challenge of devising interventions that can address stunting both in rural and urban areas. Successful social interventions in developing countries and in their rural regions, demands not only a good strategy but also a comprehensive strategy that applies different kinds of resources such as human capital, government funding, as well as supportive infrastructure.

The key challenge of developing a comprehensive strategy to reduce the deprivation that contributes to stunting is the main motivation for my research, which I hope will contribute to the dialogue and development in improving health outcomes of children and infants in Peru. In this thesis I analyze the determinants of CU by using a multilevel econometric model based on popular conceptual frameworks of undernutrition[4]. I argue that by exploring the relationship between CU and its determinants, we can contribute to the design, monitoring and evaluation of public policy that could more successfully reduce CU in Peru.

Chronic Undernutrition is a major problem of public health and its consequences are manifested throughout the human life cycle. The poor and the extreme poor are mainly affected. The most recent evidence reinforces the importance of facing CU as it has immediate negative effects. These effects include a greater likelihood of illness or premature death in children under five years of age, a greater likelihood of later entry to school, poor cognitive development, poor school performance, reduced productivity and low work capacity leading to increased costs and economic losses to the family and society (Black et al., 2008; Bhutta, et al., 2013; Crookston, et al., 2011).

There is evidence that children with CU have lower cognitive development related to anxiety and low self-esteem, with the worst emotional outcomes and behavior during adolescence (Walker, et

[4] In 1990, UNICEF developed the "Strategy for improving nutrition of children and women in developing countries" document which formed the basis of analysis in most of the papers where malnutrition or child mortality were analyzed. In this document, a conceptual framework of child undernutrition and its determinants was proposed. The document was updated in 2013 with the title "Improving child nutrition the achievable imperative for global progress".

al., 2007). Even if children experience an excellent nutritional rehabilitation process, the child malnutrition observed before 60 months of life is associated with a persistent attention deficit in adulthood regardless of socioeconomic conditions (Galler et al., 2012).

In undernutrition children more emotional problems have been identified (Liu et al, 2004; Pollit et al. , 2000; Gardner et al., 1999), as well as, decreased activity, less play and exploration (Meeks Gardner et al, 1999), less vocalization (Fernald & Grantham-McGregor, 2002), a tendency to stay closer to the mother, be more apathetic, and more inhibited (Aburto et al., 2009; Baker-Henningham et al., 2009).

Therefore, undernutrition is one of the major targets in Public Policy around the World due to its negative impacts on child health leading to increased rates of child mortality under five years of age (WHO, 2014). According to Black et al (2013), undernutrition caused 45% of the total child deaths in 2011[5], this percentage implied a staggering 3.1 million child deaths that year.

The United Nations (UN) indicates the decrease of undernutrition in any of its types is a requirement in order to achieve the Millennium Development Goals (MDGs) to reduce poverty, hunger and undernutrition (MDG1) and reduce child mortality (MDG4)[6] (UNSSC, 2010). This decision is based on the evidence that links malnutrition and child mortality (Pelletier et al., 1993) and also because there are effects of malnutrition on delayed mental development, poor school performance and reduced intellectual capacity on children (Mendez & Adair, 1999; WHO, 1999; de Onis, 2006).

[5] The estimate includes fetal growth restriction, stunting, wasting, and deficiencies of vitamin A and zinc along with suboptimum breastfeeding.

[6] The target for the MDG1 was to reduce the proportion of people who suffer from hunger by half, between 1990 and 2015, and for the MDG4 was to reduce by two-thirds over the same period. (WHO, 2014).

There are two main indicators used to analyze and to track the progress towards the achievement of the MDGs in undernutrition: i) the high prevalence of stunting and ii) high prevalence of underweight children, through the new WHO growth standards developed in 2006 (UNSSC, 2010). The first main indicator (stunting) measures CU and "it is defined as the percentage of children aged 0 to 59 months whose height for age is below minus two standard deviations (moderate and severe stunting) and minus three standard deviations (severe stunting) from the median of WHO child growth standards" (UNICEF, 2013, p. 7).

The second main indicator (underweight) reflects a combination of chronic and acute undernutrition and "it is defined as the percentage of children aged 0 to 59 months whose weight for age is below minus two standard deviations (moderate and severe underweight) from the median of the WHO child growth standard" (UNICEF, 2013, p. 7).

The monitoring of stunting is a recent addition in the reports about MDGs and this incorporation is supported on the irreversible damage done to a child's body and brain that it is different from the effects produced by children that are underweight. In fact, it is true that both, indicators of stunting and being underweight, provide understanding about the relationships and effects of dietary intake and illness.

However, stunting (height for age) is taken as a better indicator to measure the effects of undernutrition at the population level since this indicator reflects a cumulative growth deficit that has long-term consequences for adult health and human capital that cannot be reversed (Luter, Chaparro, & Muñoz, 2011; UNICEF, 2013; UNICEF, 1990; UNSSC, 2010).

The Millennium Development Goals set a 50% reduction, for both child underweight and for population undernourishment by 2015 when compared to 1990 (Gentilini & Webb, 2008).

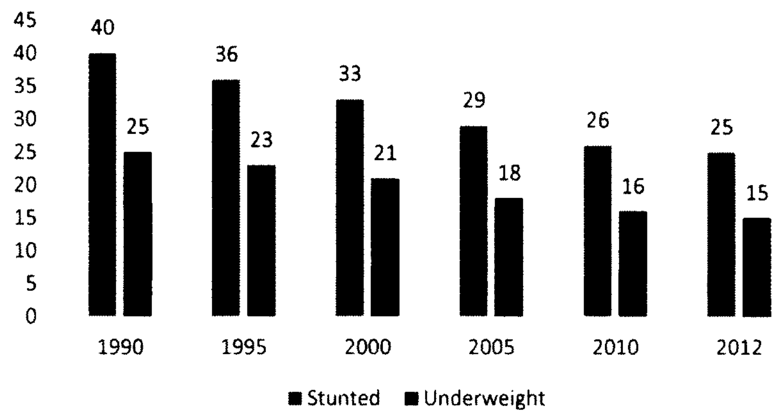
According to the data for 2012 (The World Bank, 2014) there is evidence of improvements in children's nutritional status. The percentage of underweight children is estimated to have declined from 25% in 1990 to 15% in 2012 (Figure 1.1). Stunting in children under five years of age has decreased globally from 40% to 25% over the same period (Figure 1.1).

These are encouraging results, but there is still work to be done. For example, above all other continents, Asia and Africa have the worst results and it is a concern, that there is inequality on these achievements between different regions and within countries, especially for the CU and its consequences.

In terms of absolute numbers, the number of stunted children in Asia is estimated to have reduced by more than half between 1990 and 2012. However, in Africa the number of stunted children is estimated to have increased from 46 million in 1990 to 59 million in 2012. The inequality in the achievements highlights the low probability to reach the MDG1 and their related health indicators related by 2015 (United Nations, 2014).

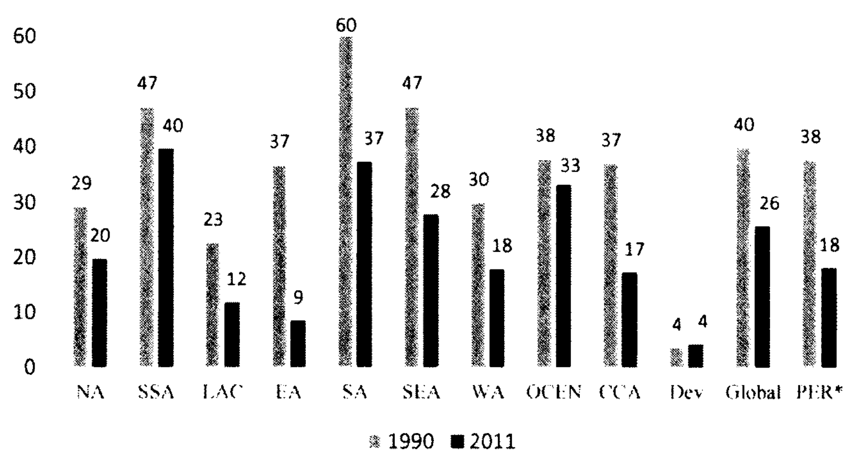
As a result, the global agenda still considers CU as a priority even after 2015. At the 65th World Health Assembly in May 2012, WHO's Member States endorsed a Comprehensive Implementation Plan (CIP) on Maternal, Infant and Child Nutrition that included a 40% reduction in the number of stunted children by 2025 against the 2010 baseline as a part of six global targets to be achieved (WHO, 2012).

Figure 1.1- Estimated Global Prevalence (%) of children under five moderately or severely stunted and of children under five moderately or severely underweight for the period 1990-2012



Note: This figure is constructed with information from integrated data of UNICEF, WHO and World Bank 1990-2012[7]

Figure 1.2- Estimated prevalence (%) and number of children under-five years of age by stunting (moderate or severe) by MDG region: 1990 and 2011



Note: This figure is constructed with information from Peruvian DHS and from integrated data of UNICEF, WHO and World Bank 1990-2012. The prevalence of stunted children in the case of Peru is for the year 2012 not for the year 2011. The Abbreviations are: NA (Northern Africa); SSA(Sub-Saharan Africa); LAC (Latin America & Caribbean); EA (Eastern Asia); SA (Southern Asia); SEA (South-Eastern Asia); WA (Western Asia); OCEN (Oceania); CCA(Caucasus & Central Asia); Dev (Developed Countries); PER(Peru)

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[7] In September 2013 UNICEF, WHO, and the World Bank updated their joint database on child malnutrition and released new global and regional estimates for 2012 (WHO, 2014).

As I pointed out, the prevalence of stunted children in the world presents a downward trend from 1990 to 2012 (Figure 1.1), which provides evidence that the efforts of undernutrition policies around the world have had some effects. However, there were no major differences in the reduction in the rates for before 2000 and after 2000, when the MDGs were set. The reduction was seven percentage points for the 1990-2000 period and eight percentage points for the 2000-2012 period, respectively.

Estimates from 2011 suggest stunting prevalence reductions of more than 40% in Asia and Latin America and the Caribbean since 1990 (Figure 1.2). On the contrary, the decreases in Africa and Oceania have been more modest (10-15%). These estimates show the inequality in the progress by regions, meaning that not only stunting is a challenge around the world, but also that we experience differences between regions.

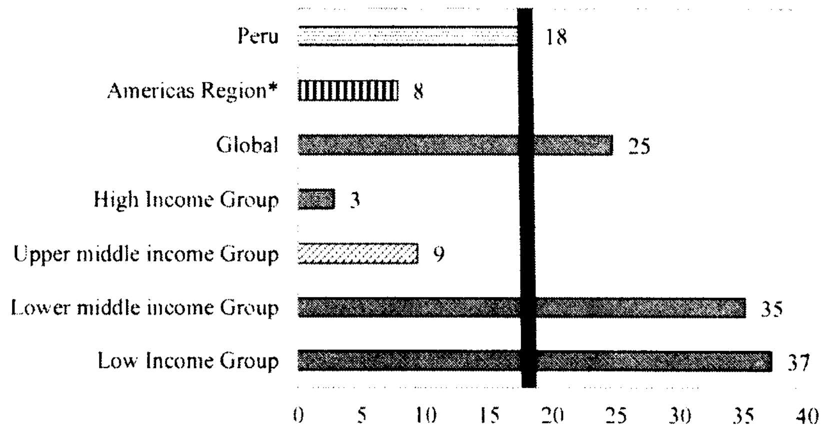
It is notable that developed countries have the lowest rate of stunting (Figure 1.2). This implies that economic development or level of income is a condition for a low stunting rate (Figure 1.3). The association between economic growth and the rate of stunting is demonstrated by Heltberg (2009).However, he concludes that the association is quite small, suggesting that it is neccesarry to implement direct interventions to reduce CU. For example, by taking into account a period of 25 years and with the assumption of only economic growth alone as an intervention to reduce CU, a country with a rate of stunting at 30% would require a constant real growth of 3.7% per capita per year in order to halve the stunting rate and if a country has a stunting rate at 50%, they would require a constant real growth of 5.9% per year to achieve this (p. s85).

This shows that CU is not an economic matter only. UNICEF (1990) points out that the causes of CU are numerous ranging from immediate causes (inadequate dietary intake and access to food), underlying (household food insecurity, inadequate care, unhealthy household environment and lack of health services) and basic causes (income poverty, lack of capital and socioeconomic conditions). The experts suggest that in order to "comprehensively address malnutrition, programs thus need to blend available knowledge and combine multiple approaches" (Bergeron & Castleman, 2012, p. 242)[8].

The main objective of my thesis is to contribute to the literature by analysing how multiple causes affect the nutrition status of the children in Peru. Peru is an interesting case because its economy has been doing well. The Peruvian economy has maintained steady growth since 2002. During the period 2002-2012 the growth of the Peruvian economy was 6.4% in real terms (MEF, 2013). However, its stunting indicator has not reached the expected results showing higher rates in comparison to other countries in Latin America with similar or even lower economic growth rates (Figure 1.4). Aa key question that arises is what kind of factors can be affecting the nutrition status of Peruvian children? The purpose of my research is to address this question.

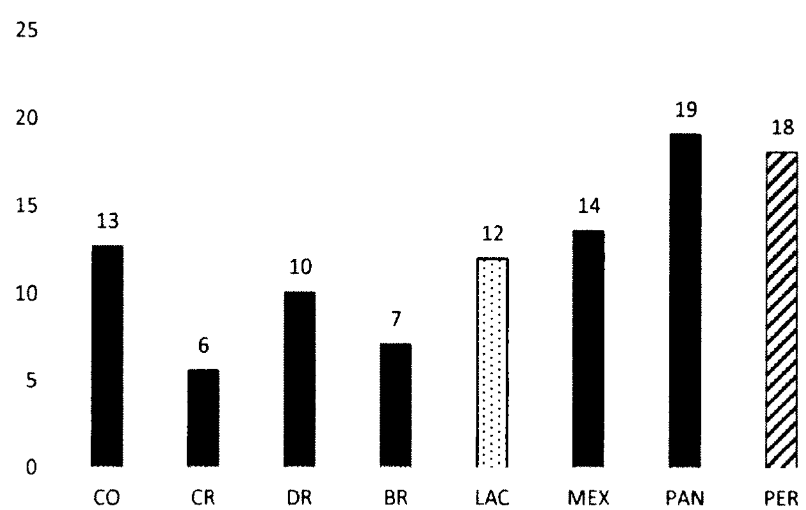
[8] There are different sectors who are pointed out to have responsibility in the policy towards CU, such as education, agriculture, health, social protection, women empowerment, development and poverty reduction.

Figure 1.3- Estimated Prevalence (%) of children under-five years of age affected by stunting (moderate or severe) for the period 2006-2012 by Income Group, Peru, Americas Region and Global



Note: This figure is constructed with information from Peruvian DHS and from integrated data of UNICEF, WHO and World Bank 1990-2012. The High, Upper, Lower and Low Income Group are classifications from the World Bank List of Economics. At regional level there are different classifications made by UNICEF, the United Nations and the World Health Organization.

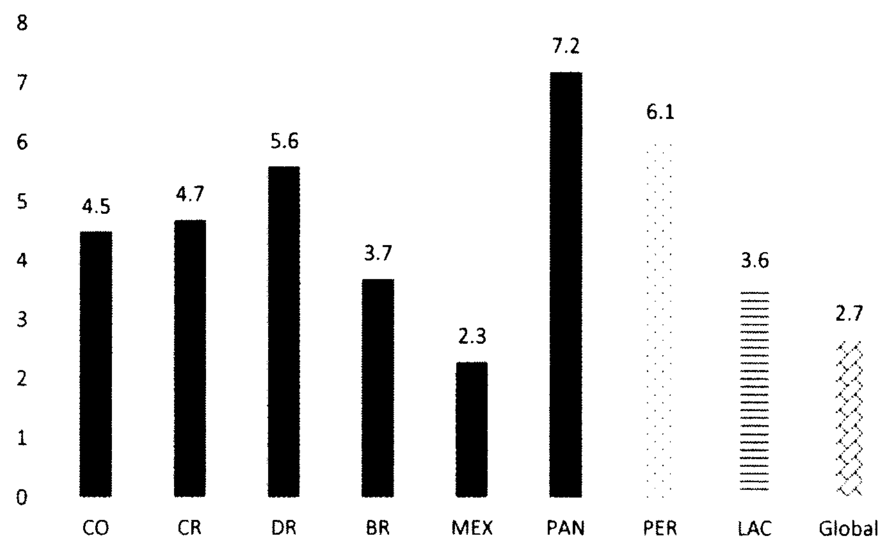
Figure 1.4- Estimated Prevalence (%) of children under-five years of age affected by stunting (moderate or severe) for the period 2006-2012 by Latin America & Caribbean and Upper Middle Income Countries (%)



Note: This figure is constructed with information from Peruvian DHS and from integrated data of UNICEF, WHO and World Bank 1990-2012. The countries are labeled as: CO (Colombia); CR(Costa Rica); DR (Dominican Republic); LAC (Latin America & Caribbean); BR (Brazil); MEX(Mexico); PAN (Panama), PER (Peru).

Peru is one of the most economically dynamic countries in Latin America – second only to Panama (Figure 1.5, MEF, 2013). However its prevalence of stunted growth in children under five years old is less promising. Going further with numbers, the Peruvian economic growth measured was twice the Global economic growth for the period 2000-2012. Economic growth in Peru is more than two points higher than Latin America Region (LAC) and at a similar level to that of Upper Middle Income (UMI) countries (Figure 1.5). Still, the prevalence of stunted children under five years old is higher than countries with worse economic indicators such as Mexico and Brazil, and it is six points more than LAC (Figure 1.4).

Figure 1.5- Gross Domestic Product (GDP) for the period 2000-2012 by Latin America & Caribbean and Upper Middle Income Countries (average annual % growth)

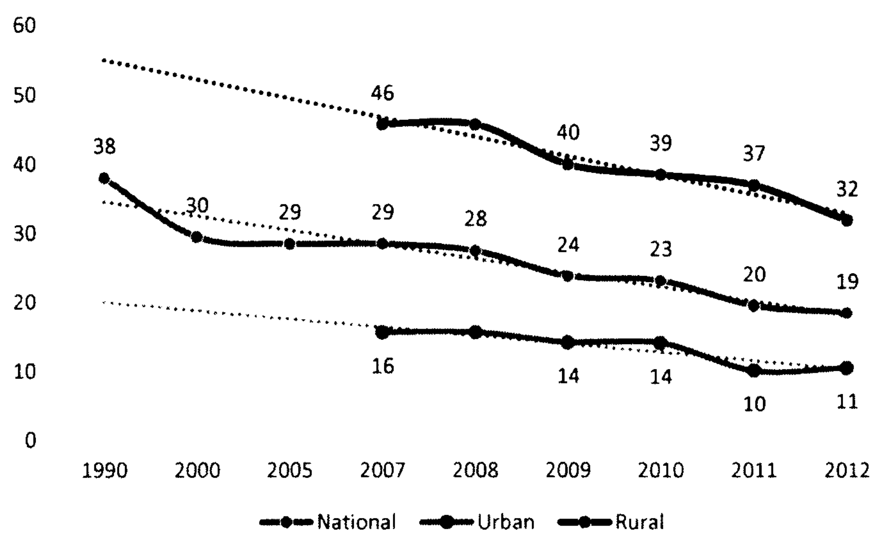


Note: This figure is constructed with information from World Bank (The World Bank, 2014). The countries are labels as: CO (Colombia); CR(Costa Rica); DR (Dominican Republic); UMI (Upper Middle Income); LAC (Latin America & Caribbean); BR (Brazil); MEX (Mexico); PAN (Panama), PER (Peru).

As mentioned before, there is a significant reduction in the prevalence of stunting in Peru from 38% in 1990 to 18% in 2012 (Figure 1.6). However, stunting remains a major problem for Peru in comparison with other countries with similar characteristics (Figures 1.4). Evidence also shows that there is inequality in stunting rates between urban and rural areas within Peru (Figure 1.6). As figure 1.6 shows, stunting had a significant decline in 2000 and then in 2009 after a phase of stagnation from 2000 to 2007, when the rate stayed close to 30%. However, during the period 2011 to 2012 there were no major changes. In 2012 the indicator was 18.1%, only 1.4 percentage points decrease from 2011.

Regardless of these improvements, the rates of stunting remain high in the rural areas. Even in urban areas the rate increased in 2012 compared to 2011 (Figure 1.6). Moreover, in some specific regions of Peru such as Huancavelica, Cajamarca and Loreto the stunting prevalence is as high as 50, 35 and 30%, respectively, showing vast regional variation. (MIDIS, 2012) .

Figure 1.6- Estimated Prevalence (%) of children under-five years of age affected by stunting (moderate or severe) in Peru for the period 1990-2012*



Note: The information is only available at national level for the whole period 1990-2012, but for urban and rural areas only since the year of 2007 (except for the year 2008) when the sample of Demographic Health Survey in Peru was increased in order to obtain significant estimations for urban and rural areas Institution (INEI, 2014).

1.2 Research Problem, Objective, Questions and Thesis Statement

The inequalities showed above demonstrate the need for studies that can help elucidate the factors behind the rates of nutritional deprivation faced by Peruvian children. This also identifies a need for us to develop ways to better help public programs or policies to reduce the problem. As I pointed out previously, this is a crucial aspect of Peru's development when considering the- vast international evidence on the negative effect that nutritional deprivation during pregnancy and the first two or three years of life has on a child's future performance in school and in the labor market. These early periods are important because of the high level of sensitivity of child growth impacted by deprivation. These impacts are proportional to the velocity of growth under normal conditions, which is extremely high in the early years (Valdivia, 2004; Hoffman & Klein, 2012). Many studies refer to the fact that there is a critical window of opportunity to prevent undernutrition, this is both during the pregnancy of the mother and during the first two years of life of a child[9]. This is when interventions can be implemented to reach optimal growth and development of the children (Bhutta et al., 2008; Bhutta et al., 2013; Crookston, et al., 2011; UNICEF, 2013).

In the 1990s, UNICEF developed a conceptual framework that emphasized several levels of causality for undernutrition (UNICEF, 1990). Pelletier (2002) pointed out that in the UNICEF conceptual framework, "malnutrition and child death are viewed as two of the manifestations of a multisectoral development problem that can be analyzed in terms of immediate, underlying and basis causes. The immediate causes are inadequate dietary intake and infectious disease; the underlying causes are household food insecurity, inadequate maternal and child care and inadequate health services and health environment; the basic causes include formal and non-formal institutions, political and ideological superstructure, economic structure and potential resources" (p. 2). The

[9] Stunting and Cognitive impairment due to under-nutrition is largely irreversible after the first two years of life; and that preference is being placed on preventing rather than incur huge economic costs towards reversing either effects.

Peruvian Government used this framework to design the Articulated Nutrition Program (ANP), the main goal of which was to decrease the prevalence of CU in children under five years old. This program was part of the implementation of BfR Policy in 2007 (MEF, 2011). The design includes different level of outcomes related to the causes identified by UNICEF conceptual framework (final, intermediate and immediate) with a particular set of interventions. However, this program is based on international data and investigations, not based on national data or the Peruvian experience.

This thesis is a result of an initiative to explore what factors predict and produce differences in CU status as measured by stunting in Peruvian children. Thus, the main objective of this study was to assess the relationship between stunting of children aged six to fifty nine months and its determinants factors in Peru. The objective was explored through the following questions:

1. What factors can explain stunting in children aged six to fifty nine months in Peru?
2. Do the same factors that affect Peruvian children during the window of opportunity of intervention (before two years old) also affect the children above two years old?
3. Is ANP affecting stunting in Peruvian children?

1.3 Contributions

I have applied a multilevel model to the data of the Demographic and Health Survey (DHS) for Peru from 2009-2012 to identify various factors affecting stunting in Peruvian children. Multilevel modelling is a "statistical technique that extends ordinary regression analysis to the situation where the data are hierarchical" (Leyland & Groenewegen, 2003, p. 267). This is the case of the DHS data as it is organized in hierarchical form which is currently the commonly used evidence base for informing public health policy. Therefore, it is important that policy makers should be aware of the methodology used in this study. Multilevel modelling is a recent technique for the social and economic field, but is already well known and established methodology in the health and education sectors (Goldstein, 2003). Still, it is not so well widespread among Peruvian investigations. It is my understanding that my research will be the first to do so with the most recent data available. Marini & Gragnolaty (2006) and Arocena (2010) used this technique with information from 2000 DHS and 2009 DHS, respectively.

This will further the pool of knowledge created by the various investigations which address CU in Peru as developed by Marini & Gragnolaty (2006), Shin (2007), Ravina & Chavez (2007), Arocena (2010), Cruzado (2012), and Gutiérrez, et al (2014), among others.

My thesis contributes in several aspects. First, I am applying both, linear and binary multilevel regressions to find the interplay of factors at the children, household, and community levels affecting CU in Peru for age groups 6 to 24 months old and 25 to 59 months old for the first time for Peru. Second, I am using most recent data from DHS in Peru, covering 4 years of the survey (2009-2012) with information of children under five born during the period 2004-2012. Third, I am introducing new variables in the analysis such as a child birth's cohort. Also, I am using the new WHO reference growth curve developed in 2006 to estimate the prevalence of stunting in Peruvian children in an oficial way since 2011 (WHO, 2006; MINSA, 2011). Finally, I am investigating the effect of the ANP on CU since its implementation in 2008.

1.4 Summary of main findings

The purpose of this thesis was to empirically examine how stunting in Peru is driven by socioeconomic, demographic, and health condition factors at the individual, household, and community levels. The results generally support the conceptual framework proposed by UNICEF (1990) and adapted by Tufts University (2001). The findings identify several factors at the individual, household and community levels that are associated with stunting in Peruvian children. Age is significant only for the children between 6 to 24 months old, but not for the children in the second group of age. This finding is related to the investigations that point out that there is a window of opportunity to implement interventions in the two first years of life, suggesting a policy of prevention (Crookston, et al., 2011; UNICEF, 2013).

Gender, mother's education level, household wealth, place of residence, low weight at birth, diarrhea, lack of access to antenatal care and delivery services, and lack of access to piped water are among factors contributing to stunting in Peru. The results also indicate that ANP may have reduced stunting among the 25 to 59 months old children.

The present thesis is organized in five chapters. In the subsequent chapter I review the literature on this topic. The first part of that chapter focuses on the literature that explore the different relationships between CU and its determinants considering the following categories: i) socioeconomic and demographic determinants, ii) child determinants – morbidity status, iii) environmental condition, and iv) child and maternal caring practices. The second part provides an overview of the literature that explores the multi-causal nature of CU and its determinants highlighting the existing hierarchical models. In the third chapter, I provide preliminary analysis of the data, the conceptual framework that guides the construction of the variables, and an explanation about some of the interactions between them and the dependent variables as used for the modelling. Also, I explain the multilevel methodology and my empirical models. The estimation results are provided in chapter four. The final chapter of this thesis, chapter five, summarizes the main findings of my thesis and discusses the limitations of the study, and proposes future investigations.

Chapter 2: Literature Review

Chronic undernutrition (CU) defined as prolonged undernutrition after a child is exposed to different factors such as inadequate food intake and illness that leads to reduced growth, that is, lower than normal height for the same age.

Chronic undernutrition is the outcome of multiple risk factors, causes and determinants. Their interplay is complex, ranging from biological and social to environmental and economic factors. Therefore, the analysis must be done carefully as variations in undernutrition are known to occur between countries of similar economic status, between regions of the same country (Wagstaff & Watanabe, 2000), and even between individuals in the same household (Bernt & Tadesse, 1997).

The goal of 50% reduction of children undernourishment as a part of the MDGs by 2015, and the goal of 40% reduction of stunted children by 2025 as a part of the implementation of Comprenhensive Implementation Plan (CIP) on Maternal, Infant and Child Nutrition by the WHO's Member States, have demanded in recent years not only the commiment of governments but also investigations that provide information to help to achieve the goals. CU, its causes and effects, and possible interventions have been extensively studied in developing countries. In this chapter, I first review the investigations related to the determinants of CU in developing countries, Latin America and Peru by taking into account first four group of determinants: i) Socioeconomic and demographic determinants, ii) Child determinants – Morbidity Status, iii) Environmental condition, and iv) Child and maternal caring practices. Then, I review the literature that considered CU and the complex relationship between the determinants.

2.1 Socioeconomic and Demographic Determinants

Van de Poel et al. (2008) uses component analysis to estimate socioeconomic status using a set of household assets and living conditions. Socieconomic inequeality was measured using the concentration index that avoids problems with dependence on the mean level of malnutrition. The study points out that "socieconomic inequality in malnutrition refers to the degree to which childhood malnutrition rates differ between more and less socially and economically advantaged groups" (p. 282). The study estimates both stunting and wasting rates in children aged up to five according to their economic status. The rates were measured using the WHO growth standars released in 2006. The investigators analyse DHS's data from 47 countries from 4 regions: 26 in sub-Saharan Africa, seven in the eastern Mediterranean, five in south and south-east Asia, nine in Latin America and the Caribbean, including Peru. Their conclusions have shown that economic inequality in malnutrition is present througouth the 47 developing countries, and in almost all the countries stunting affected the poor, however there was no clear association between average stunting and socioeconomic inequality. Moreover, reducing the overall rate of malnutrition did not necessarily lead to a reduction of inequality.

Also, Barros et al. (2010) found that stunting and overweight were usually twice as prevalent for the poor than the rich in low and middle income countries. The goal of the study was to describe the effects of social inequities on the health and nutrition of children in low and middle income countries by revieweing existing data from nearly 100 countries (DHS data and UNICEF Multiple Indicators Cluster Surveys) on socioeconomic disparities within countries as related to the use of services, nutritional status, morbilidity, and mortality. Particulary, in the case of stunting and underweigth, the analysis and estimations were based on concentration index for both prevalence of stunting and underweight. The main conclusion of this study is that the poor children are more likely of being stunted. Barros et al notes that "these inequities in health outcomes result from the fact that poor children, relative to those from wealthy families, are more likely to be exposed to disease-causing agents; once they are exposed, they are more vulnerable due to lower resistance and low coverage with preventive interventions; once they acquire a disease that requires medical treatment, they are less likely to have access to services, the quality of these services is likely to be lower, and life-saving treatments are less readily available" (p. 1).

Similar conclusions were obtained by Wagstaff & Watanabe (2000) in a study of 20 developing countries from 11 Living Standars Measurement Study (LSMS) surveys. The study concludes that the inequalities and socieconomics disadvantages in malnutrition always disfavor the poor, and it is not only that the poor have the highest rates in malnutrition, but also the rates declined with rising living standard.Particulary, the authors referred that Peru was one of the countries with highly unequal distributions, and it had both, a high average level of stunting (higher than Egypt for example) and higher poor-non poor inequality (Wagstaff & Watanabe, 2000, p. 15).

Wamani et al. (2004) examine the association of four socioeconomic indicators namely: mothers' education, fathers' education, household asset index, and land ownership with growth stunting among infants in the rural district of Hoima, Uganda. The authors implemented a cross sectional survey using two-stage sampling design to obtain 720 child/mother pairs. The results indicated a higher prevalence of stunting among children of non-educated mothers compared to mothers educated above primary school, children of non-educated fathers compared to those with fathers who were educated above secondary school, and children from households belonging to the "poorest" quintile of the asses index compared to those from the "least poor" quintile. However, adjusting all socioeconomic indicators in conditional regression analysis left mothers' education as the only independent predictor of stunting. Finally, more boys than girls were significantly stunted in poorer than wealthier socio-economic status (Wamani, Tylleskär, Nordrehaug, Tumwine, & Peterson, 2004, p. 5).

In the same vein, Smith et al. (2003) concluded that the role of the women's social status in determining their children's nutritional health is important. The study included 36 developing countries. The authors used an Ordinary Least Square (OLS) regression to analyse the relationship between stunting and underweight, with mother's status, mother's education, income, access to sanitation services, among others things. The results of the study indicate that the mother's education positive contribute to the indicator of height for age (Z-score). Mothers with high school education have a twice positive effect on stunting than mothers with only primary education.

Similary, Baldárrago (2010) investigates the relevance of the mother's education on CU. He evaluated the effect of the mother's education on child's health using height for age z-score as a proxy of the child health status. The study is based on DHS data of the year 2008. The sample included 3 958 children under five years old and their mothers. It was found that the mother's education has a positive impact on her child's growth. Part of this effect is explained for their reading and writing skills, and for the access to information (radio, tv or newspaper).

Shin (2007) studied the effect of the education of the mother on the children's on stunting (measured as a height for age z-score). Using the 2000 DHS of Peru and with a multilevel analysis the study found that in urban areas, maternal education is less important for child health than in poor rural areas, and a higher level of education has a greater effect in rural areas. Multilevel analysis shows that a significant part of the observed correlation between maternal education and child health is moderated by regional differences and community characteristics (p. 430).

Urke et al. (2011) also found that stunting is associted with geographical areas, education of the mother and socieconomic factors. They investigated the association of parents socieconomic status with child stunting in the Peruvian Andes and in Peru nationally. The data were from DHS 2004 to 2006. A comparison of two samples of children from 3 to 60 months old: a national sample (1426 childlren) and Andes sample (543 children) were selected. The socieconomic status was significantly related to stunting for both, the national and the Andes sample.The odds of stunting in the poorest wealth index quintile were significantly higher than the richest quintile. The same pattern was observed in children of mothers having incomplete primary education compared with children of mothers having complete secondary or higher education. The associations of wealth and maternal education with stunting were significantly stronger in the Andes compared with the national sample.

2.2 Child Determinants – Morbidity Status

There are several investigations that examine the relationship between related child health condition and undernutrition. The health conditions are usually diarrhea, respiratory infections and low weigth at birth.

Medhin et al. (2010) conclude that Low Birth Weight (LBW) is a factor associated with a 1.69 increased risk of CU (Table 4, p. 4). The study recruited 1 065 women in the third trimester of pregnancy from the demographic surveillance site in Butajira, south-central Ethiopia, and followed up until the infants were at one year of age. The study analyzed two indicators of undernutrition: underweight and stunting using the 2006 WHO child growth standard. By applying logistic and linear multiple regression models it was found that male gender, LBW, poor maternal nutritional status, poor household sanitary facilities and living in a rural residence are significant and strong explanatory variables. Similar findings were found by Ngoc & Kam (2008). They estimated that LBW increases by 5.69 times the risk of CU in children under five in Nghean, Vietnam (table 5, p.236). In this study, 650 child/mother pairs were selected using a two-stage cluster sampler methodology. There were estimated underweight, wasting and stunting using the reference data from the National Center for Health Statistics (NCHS)/WHO. The study explored the hierachical relationships between potential risk factors and malnutrition by using a logistic regression analysis.

Adair & Guilkey (1997) also find LBW as a strong predictor of CU for children under one year old in Philipines. The study focuses on the relationship between age-specific factors and stunting in children from birth to 24 months of age. This community-based study was conducted from 1983 to 1995 with data from nearly 3 000 children in the Cebu Longitudinal Health and Nutrition Survey. Length, morbidity, feeding and health-related data were collected every two month during home visits. Stunting was estimated using the WHO reference growth curve released in 2006. They estimated the likelihood of becoming stunted by using a multivariate discrete time hazard model. In addition to LBW, diarrhea, febrile respiratory infections, and early supplemental feeding were found to be statistically significant determinants.

Checkley et al. (2008) completed a systematic review. The review finds that high level of retarded growth and risk of CU are consequences of the number and duration of diarrhea episodes for children under 24 months old. The data covered a 20 years period (1978-1998) and five countries: Peru, Bangladesh, Guinea-Bissau, Brazil and Ghana. They found that five or more episodes of diarrhea before the age of 24 months old explain 25% of CU observed in children at the age of 24 months (p. 821).

Similary, Lee at al. (2012) estimate the impact on stunting of diarrhea episodes in children from the Peruvian Amazon (jungle). Diarrhea incidence predicted decreases in linear velocity over four and six months intervales of 0.029 and 0.028 cm/episode, respectively (p. 534). The study also analysed the adverse impact of vivax malaria. The ponderal and linear growth velocities over two, four and six month periods were examined using longitudinal models with data of 442 children under 43 months.

Concerning literature related to respiratory infections, Coles et al. (2012) investigates the effects of Stretococcuspneumoniae (Spn) infection on stunting and underweight in children at ages two, four and six months among 389 infants living in rural South India. The data was from "an Spn carriage study nested within a randomized, double-blind, placebo-controlled community trial designed to evaluate the impact of newborn vitamin A supplementation on Spn carriage in the first 6 months of life" (p. 1088). In this experiment children with Spn at two months old have 3.07 times greater risk of CU (Table 2, p. 1091) and the infection was associated with the decrease of 1.31 in height for age z-score (Table 3, p. 1091). For the case of children at six months old the decrease was in 0.59 of height for age z-score (Table 3, p. 1091), and for children at four months old there was no effect.

2.3 Environmental Conditions

Smith & Haddad (2014) estimated the effects of underlying and basic determinant of stunting in children under five years old for a 40 year period. They considered as a part of underlying determinants the access to safe drinking water and improved sanitation. The study is based on data for 116 out of total of 132 developing countries between 1970 and 2012. It uses fixed effect regression. In addition to the educacion of the mother, the access to safe drinking water and improved sanitation were strongly linked to stunting reduction. Access to safe water (25%) and improved sanitation (14%) explained 39% of the variation in stunting rates across countries and time periods (Figure 3b, p. 24).

Similar conclusions were found by Günther et al. (2011), they evaluated the relation between household access to water and sanitation and child health measured as a mortality, stunting and diarrhea. This study used a cross sectional data from 171 DHS of 70 developing countries that includes information on 1.1 million children under the age of five years over the period 1986-2007. By logistic modelling they estimated the effect of water and sanitation access on infant and child mortality, diarrhoea and stunting. Children with sanitation access have lower risk (0.87) of suferring diarrhea episodes and lower risk of mild or severe stunting (0.74). Also, children with access to improved water was associated with lower risk of diarrhoea (0.91) and lower risk of mild or severe stunting (0.92) (Table 3, p. 1202).

2.4 Child and Maternal Caring Practices

The appropriate feeding practices positively affect the growth of children. Marriott et al. (2012) analysed the relationship between eight WHO food indicators and children health status (stunting and undernutrition). The eight WHO food indicators were: i) early initiation of breastfeeding, ii) exclusive breastfeeding under six months, iii) continued breastfeeding at one year, iv) introduction of solid, semi-solid foods or soft foods, v) minimum dietary diversity vi) minimum meal frequency, vii) minimum acceptable diet, and viii) consumption of iron-rich or iron fortified food (Table1, p. 357). They used individual-level logistic regression models for different food indicators along with age, gender, mother's education and urban/rural status. The study was based on 14 countries DHS databases from 2000-2005, there were no significant association between breastfeeding initiation or exclusive breastfeeding and stunting, but there was for underweight. For children between six to eight months old, the consumption of solid foods, minimum acceptable diet, the consumption of iron-rich and dietary diversity were associated with significantly lower risk of both stunting and underweight. Also, the risks for stunting and underweight are even lower when it is also associated with maternal education (Table 6, p. 365)

Similar conclusions were found by Lamberti et al. (2011). They conducted a systematic review of literature about breastfeeding as a risk factor for selected diarrhea morbidity and mortality outcome for children under 24 months old. They conducted a random effects meta analyses in order to generate pooled relative risk by diarrhea incidence, diarrhea prevalence, diarrhea mortality, all cause of mortality and diarrhea hospitalization by group of age. The results of 18 studies show that children younger than 1 year old who did not receive exclusive breastfeeding compared to those with exclusive breastfeeding have 2.65 times the risk of diarrhea, and they are 19.48 times more likely to be hospitalized for diarrhea (Table 2, p.5).

About the access to adequate health services and CU, Penny et al. (2005) found some effects on CU. They evaluated the effects on nutrition of child oriented national programmes such as immunization, monitoring growth and development, and management of acute respiratory infections and diarrhoea in a periurban area in Trujillo, Peru. They concluded that improvement of nutritional education delivered through health services can decrease the prevalence of CU in children at age 18 months old in areas where access to food is not a limiting factor. Six pairs of health facilities were randomly selected. The types of health centers considered were: community hospitals offering maternal and perinatal specialist services; health centers with medical staff always in attendance; and health centers with more limited services. Two outcomes were considered: i) the nutritional status measured by weight, length, and Z scores for weight for age and height for age at age 18 months, ii) feeding practices, children receiving recommended feeding practices and the 24-h dietary intake of energy, iron, and zinc from complementary food at ages 6, 9, 12, and 18 months. Results were compared by use of ANOVA and non-parametric statistical tests, and random effects models were applied. The study included 187 infants from the health centers of intervention and 190 from control areas. Related to the feeding practices the adequate access to health services had a positive effect, more children at six months in the intervention areas were fed the recommend complementary nutrient at lunch than were controls. Fewer children in intervention areas failed to meet dietary requirements for energy, for iron than did controls (Table 5, p. 365). Children in control areas were more likely to fail to grow at 18 months than children in intervention groups, and had 3.04 times as much the risk of being stunted (Table 4, p.365).

Moreover, the use of health services could be linked to the level of the mother's education. Abuya et al. (2011) concluded that mother's education has an impact on the use of health services and stunting. They conducted a study with 2003 DHS data in Kenya. They estimated odd ratios in order to show the effect of maternal education on children completed immunization and stunting. Children with mothers with only a primary education were 2.17 times more likely to be fully immunized compared to those whose mothers lacked any formal education.
So far, I have reviewed the literature that focuses on a simple or several factors affecting CU and stunting, without taking into account the hierarchical nature of the relationships between the determinants. The following section reviews the literature that has considered the hierarchical nature of relationships among the determinants of CU and stunting.

2.5 The Hierarchical Models of Chronic Undernutrition and Stunting

2.5.1 Studies on Developing Countries outside Latin America

There are several investigations that analyze the multilevel causality of the determinants of CU. Such studies recognize that the determinants are intertwined with each other and are hierarchically related. In order to address these complex relationships. The studies (such as those in the case of Peru) use conceptual frameworks to understand the determinants of nutrition outcomes. The main focus is to develop multilevel relationship between the determinants and CU.

The conceptual frameworks set the determinants at different levels while recognizing the relationships between them. In this case, the authors are not concerned with the detailed characteristics of each determinant, unlike the studies in the previous section. However they focus more on the econometric and statistical methods that capture the multilevel relationships among the determinants and how they affect children's CU or stunting.

For example, Chopra (2002) takes into account the different pathways of the determinants of CU in South Africa. It considers a conceptual framework for the rural area of South Africa where they consider socioeconomic, environmental and birth weight factors (Figure 1. p. 647). The socioeconomic variables measured were: migrant father, mother's education, proportion of income, spent on food, material of housing, among others. In the case of environmental factors the main focus was on access to water, sanitation and electricity. And for the birth weight factors the variables included current breastfeeding, age of introduction of solids, weaned before 4 months, introduction of feeding and other feeding practices.

The nutritional conditions studied were underweight (weight for age z-score) and stunting (height for age z-score). The effects were measured through a multivariate analysis by taking into account first control variables as age and gender. Next all the socioeconomic variables, then environment factors and finally the birth weight variables. The results confirm the multicausality of undernutrition and that the risk factors vary according to the type of undernutrition. For stunting, low birth weight, distance form health clinic and breastfed last child were the most important risk factors. Nevertheless, mother literacy and duration of breastfeeding were not significant (Table 3, p. 650). This paper discussed the differences between the risk factors according to the type of undernutrition in order to emphasize the different policies approach that could be considered and implemented. However, it did not included other factors related to child illness or sanitation.

Ngoc & Kam (2008) constructed a conceptual framework of CU for Vietnamese children under five years old based on previous studies. In this study, the model considers three groups of variables as a determinants: i) distal factors (socioeconomic variables) ii) intermediate factors (family variables), and iii) proximal factors (individual variables) (Figure 1, p. 264). They used 2007 data from cross-sectional survey in the province of Nghean, Vietnam. A multiple logistic regression analysis was used to capture the hierarchical effects between potential factors and malnutrition. Malnutrition was estimated in its three forms, underweight (weight for age), wasting (weight for height) and stunting (height for age) based on reference data from the National Center for Health Statistics (NCHS) / WHO. The results show that malnutrition, independent of its type, was found to be a result of maternal, socio-economic and environmental factors. In the case of stunting, children in rural and mountainous areas were 1.9 times more likely to be stunted (Table 4, p. 235). Children from families that had ≥ 3 children were found to be 5.4 times more likely to be stunted than children from families with <3 children (Table 5, p. 235). The odds ratio of being stunting was lower among female children than among male children. And children between 0-11 months old were found to have a lower odds ratio, and infants with low weight at birth were 5.6 times more likely than normal birth weight infants to be stunted. Children who did not receive exclusive breastfeeding were 3.7 times more likely than children who did (Table 6, p.236). This study contributes to the literature on malnutrition in rural areas. However, it must be noted that the three types of malnutrition considered in that study have different causes that may not be explained by the same set of factors (UNICEF, 1990).

Kabubo-Mariara et al. (2008) investigated the impact of child, household and community characteristics on children's height in Kenya. These characteristics were taken from the conceptual framework proposed by UNICEF (1990). The nutritional status of the children were measured as height for age z-score, and the results were presented in four different models, two models with controls for cluster-fixed effects for both dependent variables, and the other two without such controls. The determinants were grouped by child characteristics, household characteristics, health care variables and enviromental factors. The authors conclude that for all the regressions, there were no significant unobserved community-level characteristics affecting child nutritional status.. At least one variable from each group was significant. More specifically boys were more likely to suffer CU than girls, also children of multiple births had a higher risk of being stunted than singletones. Maternal education is more important than parental education and household assets and the use of public services had a significant association with CU (Table 3, p. 374-375).

Kandala et al. (2011) analyze CU in children under five in Democratic Republic of Congo (DRC). The study takes into account the multicausal nature of CU by controlling the regressions for distal, proximate and intermediate factors following the framework proposed by UNICEF (1990). It is important to note, that both linear and nonlinear effects between the determinants and nutritional status were incorporated. They evaluated the significance of the determinants on z-score height for age estimating fixed, non-linear effects and spatial effects. CU was high in all the provinces of the DRC. However, it was significantly higher in rural areas compared to urban centers. Moreover, age, access to delivery services, education of the mother and assets index were found to affect CU status (Tables 1 and 2, p. 7-8).

Mazumdar (2012) also addressed the multicausality of CU through an adaptation of the conceptual frameworks proposed by FAO/FIVIMS and UNICEF (1990) that consider determinants at child, households and community levels (Figure 2, p.3). The author analyzed CU in children under five years old in Egypt. The data used is from 2008 DHS and child nutrition status was determined by height for age z-score for each by using the WHO reference population data in 2006 (de Onis, 2006). The total of children considered in the sample was 8 505 from 6 487 households distributed in 1 214 clusters. The research used a multilevel analysis (linear and logistic) in order to capture fixed and random effects at the three levels (child, household and community). Results indicate considerable community effects influencing a household's nutritional choices. However, education of the mother or women's decision-making power could not be linked to CU, but there was a positive association between a better nutritional status and the health service utilization as well as child care, economic status and living standards and feeding practices. The authors conclude that such results, support the hierarchical and multicausal nature of CU, addressing the effects at individual, household and community level (Table 2, p.8).

Fenske et al. (2013) studied the determinants of CU in India for children under 24 months old by using the conceptual model elaborated by UNICEF in 1990, identifying possible causes of child stunting structured by the layers (immediate, intermediate and underlying determinants). They used cross-sectional data from the Indian National Family Health Survey for 2005/2006. The methods of analysis included an additive quantile regression for four quantiles in order to capture the linear, non-linear, spatial and age-varying effects. Also, they modelled a logistic regression for stunting and severe stunting. The nutritional status of the children was analyzed by z-score for height for age and stunted (z-score $\leq$ -2), the explanatory variables were created considering the following groups: child demographics, maternal characteristics, household characteristics, regional characteristics, environmental characteristics (such as water, sanitation and hygiene, indoor air pollution, along with curative and preventive health care, breastfeeding factors, complementary feeding practices, and micronutrient deficiency) (Table 1, p. 4-6). Their results confirmed the multilevel nature of child stunting. For the 35% Z-score quantile regression at least one variable within the groups of determinants was significantly associated with the dependent variable (z-score height for age) (Table 2, p. 7-8). The variables that showed the largest effects were: child age and sex, household wealth, maternal education and Body Mass Index (BMI). They found a non-linear relationship between child stunting and the variables: maternal age, maternal BMI, birth order and number of antenatal visits (Table 2, p. 7-8). One of the strengths of this research is that through the statistical modelling they could capture linear and nonlinear effects.

2.5.2 Studies in Latin American Countries (excluding Peru)

In the case of Latin American countries, there several studies that approach CU by taking into account the multicausal characteristic of the problem. For Guatemala, Gragnolati (1999) investigates the determinants of poor child growth in rural areas (measured as height for age z-score). This study is based on the data of the Guatemalan Survey of Family Health conducted in 1995. The estimates were guided by the economic model of the family and the proximate determinants framework. The study applied multilevel models to hierarchically clustered data to control for family and community heterogeneity. Therefore, the complexity of the relationships between the determinants were taking into account by estimating fixed and random effects by individual, household and community covariates in shaping differentials in children's height. The education of the parents is found to have a positive effects on child malnutrition status. Children had a better height where community infrastructure (such as piped water and garbage disposal) and health care facilities were better (Table 5, p.39-40).

In Ecuador, the World Bank (2007) used an adaptation of the conceptual framework proposed by Tufts's University (Figure 13, p. 22). In this case, a multivariate analysis was applied with data from the 2004 Demographic and Maternal and Child Health Survey (ENDEMAIN). CU status was determined by z-score height for age and the determinants were specified at individual, household and community levels. The sample only included children under five years old. However, not all the variables considered in the conceptual framework could be included. The most important at child level were: inadequate food intake, low weight at birth and child health status (diarrhea disease, inadequate immunizations and respiratory infections). It is pointed out that the exclusion of some of the variables was needed to avoid problems of endogeneity. Although the study recognizes that hierarchical factors, it does not take into account the hierarchical form of the cross sectional data during the estimations. However, some effects were captured such as the height of the mother with a positive impact. Altitude, rural status, and household resources and composition had negative relationships with CU, whereas adequate access to sanitary conditions had a positive impact on the nutritional status of the children (Table 7, p. 24-25).

Monteiro et al. (2010) analyzed stunting in Brazilian children under five years old. The main goal was to evaluate the effects of income and basic service redistribution policies implemented by Brazilian Government through the trends in the prevalence and social distribution of child stunting over a period of 33 years (1974-2007). Although, different pathways of causes of CU were recognized by identifying underlying determinants, intermediate determinants and proximate determinants, only the underlying and intermediate determinants such as household assets, maternal education, maternal antenatal health care, water supply and sanitation services, and reproductive health indicators were included. The effects of the variables at each level were captured for the period 1996-2007 in order to explain part of the drop of CU from 37.1% to 7.1%. Prevalence of stunting for quintile was the outcome to be evaluated[10]. The data was collected from four national surveys. The study used the Slope Index of Inequality (SII) to quantify absolute socioeconomic disparities in child stunting. The SII, which is based on a weighted linear regression of the observed prevalence of stunting in the quintiles, expresses the absolute difference in outcome between the lowest and the highest quintile. Also, the changes in the rest of determinants were tested for statistical significance by fitting an interaction term between the year of the survey and the socioeconomic quintiles. The main finding is that in the last 10 years the decline in the rate of stunting was particularly steep. Also the gaps between poor and wealthy families with children under five were also reduced in terms of purchasing power;

[10] The WHO growth reference curve released in 2006 was used to estimate the prevalence.

access to education, health care and water and sanitation services; and reproductive health indicators (p. 305).

2.5.3 Studies on Peru

A few studies have analyzed CU and its determinants in Peru. Lescano (2002) use the Peruvian 1996 DHS data to explain CU trends in Peruvian children between two and four years old. This study uses variables from four categories: i) access to quality dietary, ii) access to water and sanitation, iii) access to health services, and iv) education and practices of hygiene, care and feeding (p.23) to predict the rates of prevalence of CU in seven areas of Peru: Lima Metropolitana, urban coast, urban mountain, urban jungle, rural coast, rural mountain and rural jungle. The dependent variable was a dummy (stunted or not sunted) measured according to the growth reference data of NCHS/WHO proposed in 1977. Using logistic regression, the study finds that at least one variable from each category is found significant (Table 10, p.40).

Similary, Marini & Gragnolaty (2006) analysed the nonlinear effects of altitude on child growth in Peru. This relationship was explored within a multivariate framework. They also recognize the role of the factors at community, household and individual level. They pointed out that due to the cluster nature of the data they applied a multilevel model in order to control for correlation of variables in the same cluster. The data used was from DHS collected in 2000, once again z-score height for age was the dependent variable. After controlling for characteristics of the children, families and communities, the data shows a significant nonlinear relationship between altitude and stunting, Peruvian children living at altitudes between 2500 and 3500 meters appeared to be worse off than children living at altitudes above 3500 metres. Other variables that were found to be linked to CU were education of the mother at secondary level, age of the children, and access to sanitation (Table 3, p.16-18). The multilevel analysis provided a better fit of the coefficients and allowed to captur both random and fixed effects. However, important variables at child and community level such as low birth weight, and access to health services such as growth control or vaccination were not included.

Ravina & Chávez (2009) analyzed the determinants of CU in Peruvian children under five years old by using the conceptual model of UNICEF developed in 1990 and updated in 1998 (UNICEF, 1998). The determinants were identified by immediate causes (at individual level), underlying causes (at household level) and basic causes (at society level) that were intertwined (p.21). The data was collected from pooled DHS for the years 1992, 1996, 2000 and 2004-2005. The dependant variable was the z-score height for age according to the growth reference database of WHO. The explanatory variables were: breastfeeding, diarrhea episodes, respiratory infections, birth order, sex of the child, age, education of the mother, fixed assets of the household, access to sanitation and water services, among others. The study included three linear regressions: OLS, fixed effects at cluster level and random effects at individual level, suggesting that the fixed effect model is the most appropiate. The variables that were found associated with CU were breastfeeding, diahrrea, age of the children and access to water and sanitation. The study concludes that endogeneity of the variables was a limitation.

Arocena (2010) estimated effects of location of the Regional Health Directions and child and household variables on stuning for children under five years old. It is implemented a logistic multilevel regression using 2008 DHS data. The location of Regional Health Directions, the education of the mother, mother's height, economic status of the household and the type of floor of the house were associated with the stunted status of Peruvian children (p. 50). However, the study does not indicate how many levels there were considered.

Gutiérrez et al. (2014) estimated statistical probabilities for being stunted (height for age ≤ 2 SD below the mean) for Peruvian children under five years of age using 2011 DHS data. They explored the association of factors such as sex, age, geographic location, education of the mother, wealth index, natural region, access to water, access to sanitation, public health insurance, altitude, child illness, among others. The calculation of the adjusted odds ratios showed significant differenes between CU in mother's education, Andes region. altitudes greater than 2500 m, presence of two or more children in household, and being the third or succesive child (p. 108). However, hierachical relationships are not explained in this study.

The reviewed literature suggest that it is important to consider the multicausal relationship between CU or stunting and its determinants. The determinants are hierarchically related. The conceptual frameworks cited in the investigations considered at least three layers of group of determinants. My thesis also takes into account the complex relationship between stunting and its determinants. However, I consider additional determinants related to the Peruvian context, such as APN and its possible effect on stunting.

Some of the researchers cited above mention that due to the hierachical nature of the data, it is necessary to use multilevel analysis that captures the effects of the determinants in the different levels (child, household and community level). In the case of Peru, Marini & Gragnolaty (2006) and Arocena (2010) used that method to analyse stunting in Peruvian children under five years old. However, the former study is on Peruvian children born before 2000. It was before the political reforms in Peru and the creation of the Peruvian regions. In the second study, the analysis is based on Peruvian children born from 2003 to 2008, when the rates of stunting were stagnent. My thesis considers children born from 2006 to 2012, when the national rate of stunting presents a downward trend at least from 2008 to 2012 that may allow to capture different effects from previous studies in Peru.

Chapter 3: Data and Methods

3.1 Data

The database used for the analysis in this thesis is taken from the Peruvian Demographic and Health Survey (DHS) [11]. The data has been pooled from the years 2009, 2010, 2011 and 2012. The data presents a hierarchical structure and has comparable information on community and household characteristics as well as on nutrition and health of women aged 15-49 and their children under five years old at the time of the survey. The samples cover all Peruvian regions, and both urban and rural areas. All women registered as living in the households were interviewed.

The database contains basic information of 38, 766 Peruvian children under five years old (from 0 to 59 months), in 30, 446 households and in 2, 259 clusters or Primary Sampling Unit (PSU). The number of children from 6 to 24 months old is 12, 149 in 11, 616 households and 2, 186 clusters (PSU), and the number of children from 25 to 59 months is 23, 277 in 20, 860 households and 2, 245 clusters (PSU). The total number of children between 6-59 months old is 35 326. However, there is a high proportion of missing data (up to 63% in some cases such as diversity of food). Therefore, the number of observations vary between models depending on the variables included in the model.

The information is about children (provided by the mother), their household and their area of residence. Due to the nature of the data, a hierarchical model similar to other studies such as in

[11] The databases are available online at http://dhsprogram.com/Where-We-Work/Country-Main.cfm?ctry_id=33&c=Peru&Country=Peru&cn=&r=6 or at http://iinei.inei.gob.pe/microdatos/

Marini & Gragnolaty (2006) and Mazumbar (2012) is used. Child and mother are considered to be nested within the same household, which in turn is nested into the community (PSU) variable.

The DHS data is cross-sectional which can cause some difficulties during the interpretation of the results, as cross-sectional studies may not provide definitive information about cause-and-effect relationships (Kuhn et al, 1997). DHS is the main source to estimate health indicators around the world and in Peru the database is used to estimate the National health indicators and it is managed by the National Institute of Statistics (INEI, 2014).

The key aim of DHS "is to provide quality data for policy development and programme planning, monitoring and evaluation. To build the policy and programmatic evidence base, DHS data must first be transformed into information, which must then be made accessible to decision-makers" (Short et al., 2012, p. 604).

3.1.1 Summary of statistics

The summary of data, statistics, and the variables in the sample used in the present study are given in the following tables:

Table 3.1- Summary of statistics

Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
Height for age z-score(continuous variable)	0-5	3 340	-.8452246		
	6-24	12 149	-1.243199		
	25-59	23 277	-1.292984		

Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
	Total	38 766	-1.238804		
Stunted (Dummy variable)	0-5	3 221	.1477802	2 745	476
	6-24	11 861	.2468595	8 933	2 928
	25-59	22 765	.2513508	17 043	5 722
	Total	37 847	.2411288	9 126	28 721
Age (months) (hc1), continuous variable	0-5	3 340	2.785629		
	6-24	12 149	15.0214		
	25-59	23 277	42.17378		
	Total	38 766	30.2708		
Gender, male (0), female (1)	0-5	3 340	0.4868263	1 714	1 626
	6-24	12 149	0.4934563	6 154	5 995
	25-59	23 277	0.4955106	11743	11 534
	Total	38 766	0.4941186	19 611	19 155
Birth's Cohort					
-Cohorts 2004 and 2005; "coh200405" (1), otherwise (0)	0-5	3 340	0	3 340	0
	6-24	12 149	0	12 149	0
	25-59	23 277	0.1697384	19 326	3 951
	Total	38 766	0.1019192	34 815	3 951
	0-5	3 340	0	3 340	0
	6-24	12 149	0	12 149	0

Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
-Cohort 2006; "coh2006" (1); otherwise (0)	25-59	23 277	0.2039782	18 529	4 748
	Total	38 766	0.1224785	34 018	4 748
-Cohort 2007; "coh2007" (1); otherwise (0)	0-5	3 340	0	3 340	0
	6-24	12 149	.0753972	11233	916
	25-59	23 277	.2287236	17 953	5 324
	Total	38 766	0.1609658	32 526	6 240
-Cohort 2008; "coh2008" (1); otherwise (0)	0-5	3 340	0.0344311	3 225	115
	6-24	12 149	0.2406782	9 225	2 924
	25-59	23 277	0.2213773	18 124	5 153
	Total	38 766	0.2113192	30 574	8 192
-Cohort 2009; "coh2009" (1); otherwise (0)	0-5	3 340	0.2649701	2 455	885
	6-24	12 149	0.2471808	9 146	3 003
	25-59	23 277	0.1312884	20 221	3 056
	Total	38 766	0.179126	31 822	6 944
-Cohort 2010; "coh2010" (1); otherwise (0)	0-5	3 340	0.2329341	2 562	778
	6-24	12 149	0.2436415	9 189	2 960
	25-59	23 277	0.0448941	22 232	1 045
	Total	38 766	0.1233813	33 983	4 783
	0-5	3 340	0.2389222	2 542	798
	6-24	12 149	0.1672566	10 117	2 032

Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
-Cohort 2011; "coh2011" (1); otherwise (0)	25-59	23 277	0	23 277	0
	Total	38 766	0.0730021	35 936	2 830
-Cohort 2012; "coh2012" (1); otherwise (0)	0-5	3 340	0.2287425	2 576	764
	6-24	12 149	0.0258457	11 835	314
	25-59	23 277	0	23 277	0
	Total	38 766	0.0278079	37 688	1 078
Access to diversity of food; Access to less than 4 types of food (1); otherwise (0)	0-5	519	0.9749518	13	506
	6-24	8 085	0.2512059	6 054	2 031
	25-59	4 321	0.1603795	3 628	693
	Total	12 925	0.2499033	9 695	3 230
Low Birth Weight; birth weight <2.5 kg (1); otherwise (0)	0-5	2 921	0.0568299	2 755	166
	6-24	10 624	0.0701242	9 879	745
	25-59	18 969	0.0779166	17 491	1 478
	Total	32 514	0.073476	30 125	2 389
Diarrheal disease; if child had diarrhea in the last 2 weeks (1); otherwise (0)	0-5	3 189	0.1059893	2 851	338
	6-24	11 582	0.2311345	8 905	2 677
	25-59	13 720	0.1197522	12 077	1 643
	Total	28 491	0.1634902	23 833	4 658
Acute respiratory infections; ; if child had	0-5	3 189	0.1326435	2 851	338
	6-24	11 582	0.1955621	8 905	2 677

Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
cough in the last 2 weeks (1); otherwise (0)	25-59	21 319	0.1456447	12 077	1 643
	Total	36 090	0.1605154	23 833	4 658
Mother's education; if the mother completed secondary school or higher level of education (1); otherwise (0)	0-5	3 330	0.6543544	1 151	2 179
	6-24	11 949	0.6331074	4 384	7 565
	25-59	22 049	0.5861037	9 126	12 923
	Total	37 328	0.6072385	14 661	22 667
Access to delivery services; if the mother has not received delivery services (1), otherwise (0)	0-5	3 174	0.1792691	2 605	569
	6-24	11 363	0.1880665	9 226	2 137
	25-59	17 120	0.2098131	13 528	3 592
	Total	3 1 657	0.1989449	25 359	6 298
Access to antenatal care; if the mother has received at least 6 control during pregnancy (1); otherwise (0)	0-5	3 165	0.7740916	715	2 450
	6-24	11 283	0.8003191	2 253	9 030
	25-59	15 614	0.8229794	2 764	12 850
	Total	30 062	0.8093274	5 732	24 330
Wealth Index Score					
-quintiln1, household in the poorest quintile (1); otherwise (0)	0-5	3 340	0.3098802	2 305	1 035
	6-24	12 149	0.3068565	8 421	3 728
	25-59	23 277	0.3182541	15 869	7 408
	Total	38 766	0.3139607	26 595	12 171
	0-5	3 340	0.2790419	2 408	932

Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
-quintiln2, household in the poorer quintile (1); otherwise (0)	6-24	12 149	0.2643839	8 937	3 212
	25-59	23 277	0.264553	17 119	6 158
	Total	38 766	0.2657483	28 464	10 302
-quintiln3, household in the middle quintile (1); otherwise (0)	0-5	3 340	0.2125749	2 630	710
	6-24	12 149	0.2158202	9 527	2 622
	25-59	23 277	0.2066417	18 467	4 810
	Total	38 766	0.2100294	30 624	8 142
-quintiln4, household in the richer quintile (1); otherwise (0)	0-5	3 340	0.1254491	2 921	419
	6-24	12 149	0.138283	10 469	1 680
	25-59	23 277	0.1351978	20 130	3 147
	Total	38 766	0.1353248	33 520	5 246
-quintiln5, household in the richest quintile (1); otherwise (0)	0-5	3 340	0.0730539	3 096	244
	6-24	12 149	0.0746564	11 242	907
	25-59	23 277	0.0753534	21 523	1 754
	Total	38 766	0.0749368	35 861	2 905
Access to growth control, child has received growth control services according to the norm (1); otherwise (0)	0-5	3 186	0.1848713	2 384	800
	6-24	11 565	0.0999568	5 805	5 741
	25-59	21 230	0.0581253	16 410	4 742
	Total	35 981	0.0827937	24 599	11 283
	0-5	3 189	0.9708373	93	2 276

Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
Access to immunization services child has received vaccines according to the norm (1); otherwise (0)	6-24	11 582	0.6040408	4 586	6 996
	25-59	6 683	0.3405656	4 407	2 276
	Total	21 454	0.5764892	9 086	12 368
Access to treated water, household has not access to treated water (1), otherwise (0)	0-5	3 340	0.2763473	2 417	923
	6-24	12 149	0.2693226	8 887	3 272
	25-59	23 277	0.2729304	16 924	6 353
	Total	38 766	0.2720941	28 218	10 548
Access to water, household has not access to piped water (1), otherwise (0)	0-5	3 340	0.3281437	2 244	1 096
	6-24	12 149	0.3243065	8 209	3 940
	25-59	23 277	0.320531	15 186	7 461
	Total	38 766	0.3223701	26 269	12 497
Access to improve sanitation; household has not access to improve sanitation (1), otherwise (0)	0-5	3 340	0.5835329	1 391	1 949
	6-24	12 149	0.5880319	5 005	7 144
	25-59	23 277	0.5781243	9 820	13 457
	Total	38 766	0.5816953	16 216	22 550
Area of residence; if the cluster is in rural area (1), urban area (0)	0-5	3 340	0.4508982	1 834	1 506
	6-24	12 149	0.4583924	6 785	5 364
	25-59	23 277	0.4583924	12 607	10 670
	Total	38 766	0.4524583	21 226	17 540

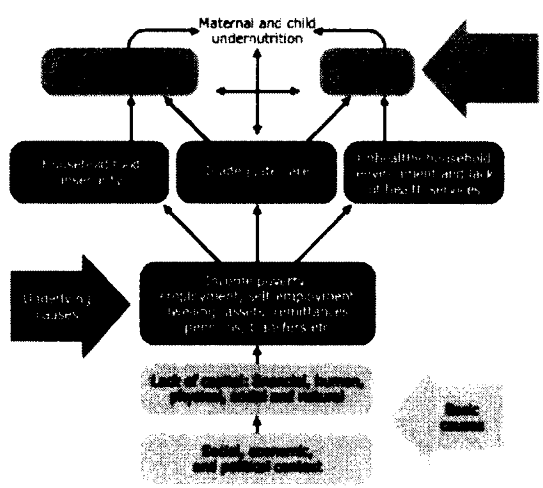
Variables	Age in months	Number of Observations	Mean	Dummy	
				0	1
Place of Residence					
-Lima Metropolitana; if the cluster is in Lima Metropolitana (1); otherwise (0)	0-5	3 340	0.0625749	3 131	209
	6-24	12 149	0.0704585	11 293	856
	25-59	23 277	0.0663316	21 733	1 544
	Total	38 766	0.0673012	36 157	2 609
-Rest Coast Area; if the cluster is in rest of the coast area (1); otherwise (0)	0-5	3 340	0.2416168	2 533	807
	6-24	12 149	0.240349	9 229	2 920
	25-59	23 277	0.2366714	17 768	5 509
	Total	38 766	0.23825	29 530	9 236
-Mountain or Andes Area; if the cluster is in the Mountain of Andes area (1); otherwise (0)	0-5	3 340	0.395509	2 019	1 321
	6-24	12 149	0.392131	7 385	4 764
	25-59	23 277	0.4157323	13 600	9 677
	Total	38 766	0.4065934	23 004	15 762
-Jungle Area; if the cluster is in the Jungle area (1); otherwise (0	0-5	3 340	0.3002994	2 337	1 003
	6-24	12 149	0.2970615	8 540	3 609
	25-59	23 277	0.2812648	16 730	6 547
	Total	38 766	0.2878553	27 607	11 159

3.2 Conceptual Frameworks

In order to guide the analysis of the relationships between the variables, this thesis uses two conceptual models. First, is the conceptual framework designed by UNICEF (1990) as part of its

Nutrition Strategy. It was updated in UNICEF (1998) and in Black, et al (2008). This framework is shown in Figure 3.1. It captures the multifactorial causality of undernutrition. The strength of this framework is that it recognizes and integrates the biomedical as well as the underlying socieconomic determinants of undernutrition. The framework considers three layers of causality: immediate, underlying and basic. The inmediate causes are at the individual level, the underlying causes influence households and communities, and the basic causes are at the structural level of the society, including the environmental, economic, and socio-political contextual factors, with poverty having a central role at this level.

Figure 3.1- UNICEF Conceptual Framework of Undernutrition



(Source: Black, et al. Maternal and child undernutrition: global and regional exposures and healthconsequences. 2008 – Figure 1, p. 244)

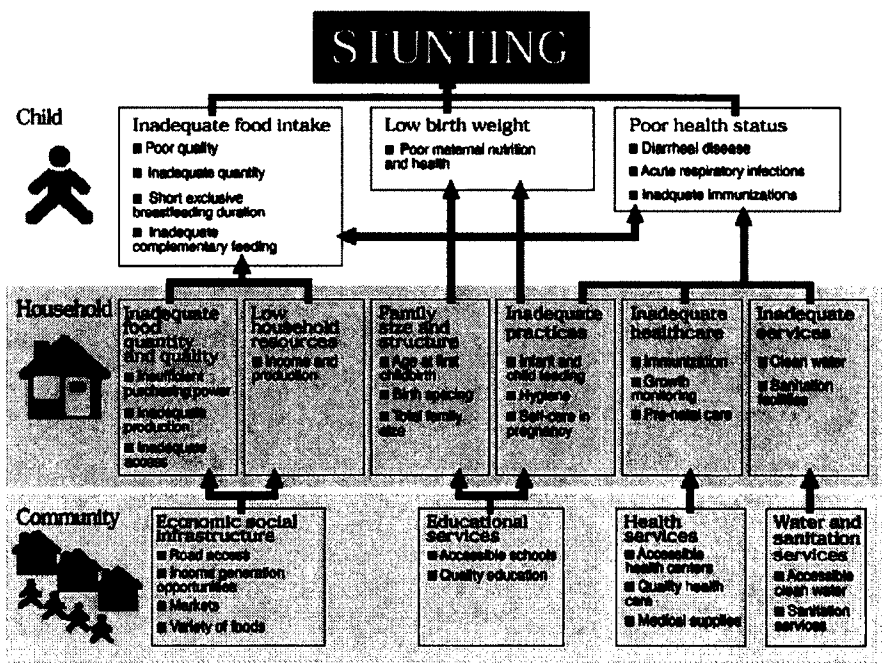
However, in order to model the interactions of the variables, it is required specific information. For example, one of the immediate causes is diseases. What kind of disease must be taken into consideration for the Peruvian context? According to Moradi (2009) "the list can include diarrhoea, pneumonia and other respiratory illnesses, diphtheria, measles, malaria, yellow fever, sleeping scikness, dengue, plague, smallpox, schistosomiasis and other parasites like hookworms but their relevance depends on the epidemiological environment" (p. 16)

The adaptation of the UNICEF framework for stunting developed by Tufts University (2001) is useful because its focus is on stunting, and also specifies the general causes proposed in the UNICEF framework, such as diarrhea and acute respiratory infections instead of diseases. This adaptation takes into acount the particular characteristis of Peruvian context. Also it considers most of the factors and the causal relationships that the Peruvian government assumed during the desing and implementation of the Articulated Nutrition Program (ANP) with the reduction of the prevalence of stunting in children under five years old as the final outcome. ANP is part of the Budget for Results policy (BfR) that has been implemented in Peru since 2007 (Cruzado, 2012; MIDIS, 2012; MEF, 2011).

The determinants at the immediate and intermediate level have been laid out, isolating factors operating at the community, household and child level. This framework gives a schematic overview of the causes of CU as shown in Figure 3.2. At the individual or child level there are the immediate causes: poor health status, inadequate food consumption and low birth weight, all of which, have possible explanations or causes. For example, in poor health three possibilities are pointed out i) diarrheal disease, ii) acute respiratory infections and iii) inadequate immunizations; Low birth weight is considered to be caused by the poor maternal and nutrition health. And inadequate food intake include i) poor quality, ii) inadequate quantity, iii) short exclusive breastfeeding duration and iv) inadequate complementary feeding.

The above factors are linked to factors that are part of the underlying causes at the household level. For example, households with low incomes lead to low food intake in children. Large family sizes and short birth spacing lead to low birth weight, as do poor feeding practices during pregnancy. Poor feeding practices can also lead to inadequate food intake in children, even in households that do not face economic constraints. Inadequate water and sanitation measures lead to increase in diseases. Some of the factors identified at this level of the model are linked to the behaviour of individuals, mainly mothers and families. Feeding practices, health care and hygiene practised at home are all critical determinants of the adequate growth of the children. Similarly, the household level causes are affected by the factors at the community level: the local economic and social infrastructure, the educational system, the existing health services and the water and sanitation system all provide critical effects on the determinants at the household level.

Figure 3.2- Conceptual Framework of Stunting in Peru



Source: (Reducción de la Desnutrición Crónica en el Perú: Propuesta para una Estrategia Nacional.TuftsUniversity, 2001, p. 13)

Both conceptual frameworks provide a better understanding about the different pathways related to undernutrition and stunting. However, they do not assign relative weights to the different pathways, which makes it difficult for decision makers to choose the most cost-effective interventions. To have more information, it is necessary to apply them in a specific context, with the best available methodology and data.

It must be noticed that the hierarchical form of the framework and the variables are somewhat related between levels. Therefore their association to stunting is not necessarily directly causal. For example, optimum water access may not be statistically significant in a regression model for stunting but it can be a key variable for diarrhea, which is linked to stunting. In this sense, if a model points out that access to water is not significant for stunting, it does not mean that interventions to improve water resources should not be considered as part of a strategy to reduce CU .Thus, taking into account these links will provide adequate conclusions and appropriate recommendations.

3.3 Methods

3.3.1 The Empirical Models

3.3.1.1 Dependent Variable: Chronic Undernutrition Status

Undernutrition status in children is commonly determined by using anthropometric information[12]. In the case of CU status the basic information and measurement used is the height-for-age (WFP, 2005; de Onis, 2008; Mora, 1989; de Onis et al, 2006). That involves the use of growth standards and/or growth references for assessing children growth status and well-being (Wang et al, 2006). A growth standard reflects optimal growth, suggesting that all children have potential to achieve that level, while a growth reference is simply the distribution used for comparison. The anthropometric indices can be expressed in relationship to the reference

[12] The basic information and measurements and measurement that constitute anthropometric measurements in children are: age, sex, length, height, weight, and oedema. "The measurements are the key building blocks of anthropometrics and are essential for measuring and classifying nutritional status in children under 5 years" (WFP, 2005, p. 13)

population by three different statistical terms: i) standard deviations from the median (Z-score), ii) percentage of the median or, iii) percentiles (WHO, 2006; Wang & Chen, 2012; de Onis, 2008).

For population-based assessment, including surveys and nutritional surveillance, the preferred and most common way of expressing anthropometric indices is in the form of Z-scores. (WFP, 2005; de Onis M, 2008; WHO, 2006). According to WHO (2006) and de Onis (2008) the main advantage of z-scores is that they can be described in terms of means and standard deviations of population or subpopulations[13]. The z-score is measured by the standard deviation of the height of the child relative to the median size of healthy children, as determined by the reference population. The International Growth Reference Curves are normalized, that means that in the case of height-for-age: at each age, there is a normal distribution of heights. This is really helpful from a statistic point of view because that implies that the observed Z-score for age from a population are likely to be normally distributed so it can be applied regressions and t-tests where the normality is assumed (Gorstein, et al., 1994, p. 276).

The formula for calculating the Z-score is:

$$height\ for\ age\ z - score = \frac{measured\ value - median\ of\ reference\ population}{Standard\ deviation\ of\ the\ reference\ population}$$

Also, the use of z-score for age allows to easily determine the proportion of children from a group of population who fail or achieve the reference growth by falling below or above a cut-point, so the prevalence of stunting can be calculated (Gorstein, et al., 1994). In general, this cut-

[13] According to the same authors this cannot be meaningfully done with percentiles. Moreover, at the extreme of the distribution, large changes in height or weight are not necessarily reflected in changes in percentile values. The percent of median is deficient relative to the z-score in that it expresses deviation from the reference median without standardizing for the variability in the reference population.

off is -2 standard deviations (SD) from the median. This criterion is supported by the statistical property where 95% of observations fall within 2 standard deviations from the mean (or median). According to the WHO (2006), the values of -3.0 to less than -2.0 indicate moderate stunting, but when this value reaches -3 SD, it is considered to be severe stunting (WHO, 2006; Wang & Chen, 2012).

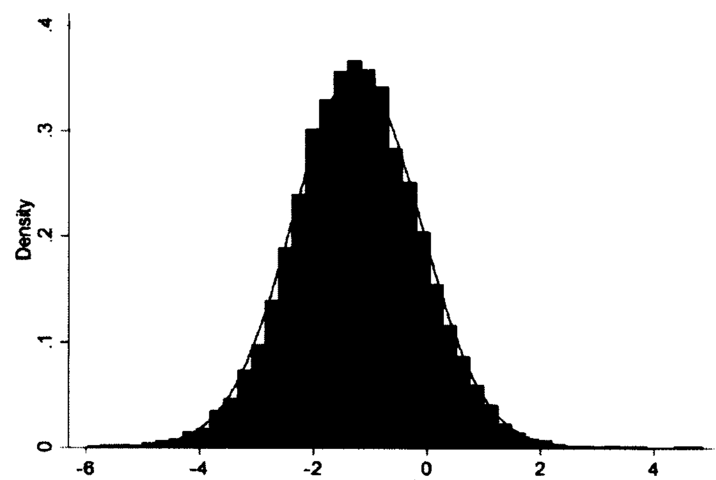
It is important to explain about all the types of growth curves of the reference population, because the value of the z-score depends on the adoption of a particular set of growth curve. In 2006, the WHO published the height of reference children obtained as a result of a longitudinal study from six countries representing different regions of the world: Brazil, Ghana, India, Norway, Oman and the United States (Onyango, et al., 2007). This set of growth references is recommended by WHO since year 2006 (WHO Multicentre Group Reference Study, 2006). The recommendation about the use of WHO/2006 for international reference started because some concerns were raised that the use of National Center of Health Statistics (NCHS)-WHO/1977 growth reference's curves "may lead to the early introduction of complementary foods in exclusively breast-fed infants, which often has adverse consequences for the health and nutritional well-being of infants" (de Onis, 2008, p. 119).

Its adoption was evaluated for different countries since then, for example the United States (Grummer-Strawn et al. , 2010) and Australia (Australian Health Ministers Conference, 2009) decided to take them into account in 2010 for children under two years old after a period of three years of evaluation. For Peru, the adoption was in 2011 and it was for children from 0 to 59 months old, making it official through the Ministerial Resolution of the Health Ministry (MINSA, 2011). Prior to the evaluation, most countries used the growth charts developed by the

US NCHS in 1977: the NCHS-WHO/1977, or the CDC/2000 released by the US Center for Disease Control (CDC) in 2000.

I use the standardized height for age Z-score as the dependent variable for Peruvian children under five years of age according to the WHO/2006 growth curve reference. The Figure 3.3 shows a histogram and kernel density of the distribution of the Z-scores of Peruvian children under five years old in my database.

Figure 3.3- Histogram, kernel density of height for age z-score



Source: Peruvian DHS data 2009-2012

3.3.1.2 Independent Variables

The selection of the explanatory or predictor variables is guided by the conceptual framework outlined in section 3.2 regarding determinants at individual, household and community level. Unfortunately, not all of the determinants are available in the survey, especially those at the "community" level[14]. The measurement of each variable is obtained from the DHS database and

[14] It is important to recognize that given the data source used for this analysis there are limitations that are worth mentioning. The DHS data set uses a standard questionnaire approach with a predetermined set of variables. The

questionnaires using the definitions for the indicators used by the National Institute of Statistics of Peru and based on UNICEF and WHO definitions (INEI, 2014; UNICEF, 2013; WHO, 2014). Also, I follow the guide elaborated by Rutstein & Rojas (2006) and provided by the Measure DHS/ICF International team of the DHS in order to create the explanatory variables for use in the Statistical Packages[15].

I am interested in the analysis of associations between CU and the explanatory variables in the context of the Budget for Results (BfR) approach that has been implemented since 2008 by the Ministry of Economy. BfR seeks to organize budgetary management around those outcomes that citizens require and value (MEF, 2011). Five Strategic Programs were initially defined as part of BfR, which responded to 11 priority actions for early childhood established by the Government of Peru as related to the Millennium Development Goals. These actions were translated into five outcomes to be achieved through implementation of RBB. The five outcomes were: (i) reducing chronic malnutrition in children younger than five, (ii) reducing neonatal and maternal mortality, (iii) improving learning attainments in children between six and seven years old children; (iv) improving access to identity (birth's registration); and, (v) improving access to basic social services and market opportunities. Behind the formulation of the first strategic programs there was a clear focus on reducing poverty and social exclusion, as well as on improving the quality of life of Peruvians (Cruzado, 2012, p. 2).

One of the program was the Articulated Nutrition Program (ANP) designed by the BfR methodology, linking results with outputs within an evidence-based logical model. The ultimate

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focus is primarily on gathering demographic, health, and nutrition information. The surveys also collect basic data on a number of other aspects such as maternal employment, use of alternative childcare arrangements, housing quality, and ownership of assets. However, information on these constructs is limited in scope.

[15] I use two programs SPSS 21 and Stata 12 in order to create the variables.

goal of the ANP is to reduce the prevalence of CU in children under five years old. To achieve this objective, the program focuses on a set of intermediate outcomes that the literature identified as important determinants of child malnutrition: i) Reducing incidence of low birth weight through improvement in the nutrition of pregnant women and control of infections during the first term of the pregnancy, ii) Reducing incidence of acute diarrhea, respiratory infections and other prevalent diseases, and iii) Improving adequate dietary intake for children under 36 months (MEF, 2011).

The current DHS database does not allow for a direct examination of the effects of ANP program on CU. However, I use a "cohort" variable that could capture the potential impact of the program on CU.

A detailed overview of variables, both dependent and independent, and their creation is provided in Appendix 1.

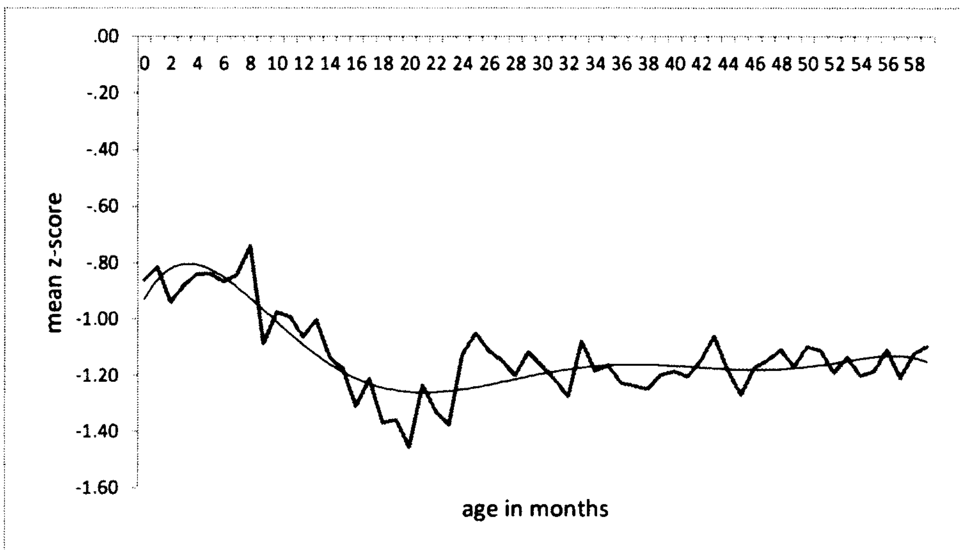
3.3.1.3 Modeling Approach

Some researchers have directly dealt with non-linear relationships between the dependent variable and the explanatory variables in their analysis of CU in children under five years old. For example, Marini & Gragnolaty (2006) show the non linear effects of altitude on child growth in Peru. In a similar way Kandala, et al (2011) explore the effects of geographic locations on malnutrition among children in the Democratic Republic of Congo (DCR). In both investigations the main purporse is to determine those nonlinear effects (altitude or geographic impact).

Also, Gräb (2009) analyzes and points out that the nonlinearity relationship between some of the predictor variables with the response variable is one of the challenging situations that researchers in malnutrition in children must be face. So, the assumption of a strictly linear effect on the response variable (height for age z-score) may not be be appropriate for all the cases. In the case of the present research I find similarities to Gräb (2009) and Marini & Gragnolaty (2006), where there are nonlinear trends between the height for age z-score for Peruvian children under five years old, and the variables breastfeeding and geographic altitude.

As shown in Figure 3.4, it is clear that the growth trajectory by age is nonlinear. The decline in children's growth as measured by z-score for age is sharp between the ages of 6 and 24 months and then slows down, changing the form of the trajectory. With this in mind, following the recommendations of Rabe-Hesketh & Skrondal (2012), I split the sample into 0-5, 6-24 and 25-59 months old age groups (See Figures 3.5 - 3.7). The line-segments were fitted to show the age-group specific trajectories.

Figure 3.4- Trend and line of mean height for age z-score by children's age

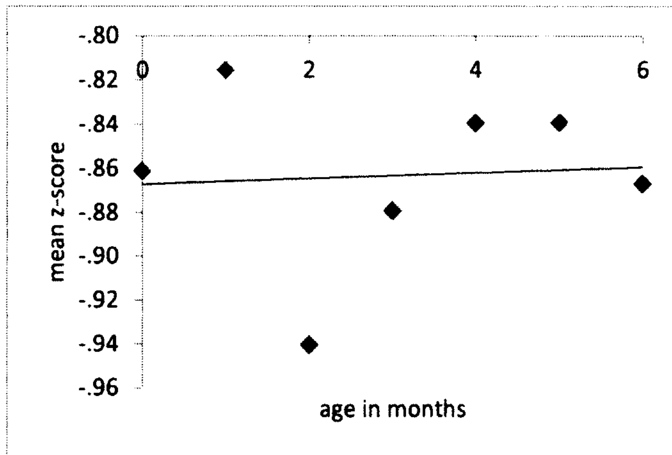


Source: Peruvian DHS data 2009-2012

It must be noted that there are fewer observations for children under six months old. The main purpose of my research is to analyse the determinants of CU older than 6 months. As Arocena

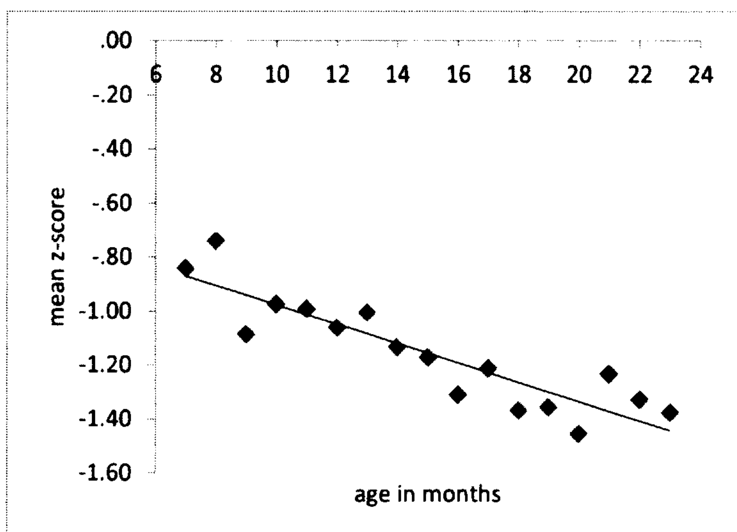
(2010) points out we should focus on children older than six or 12 months old because their stunting status is not yet evident.

Figure 3.5-Trend and line of mean for height for age z-score by children's before 6 months old



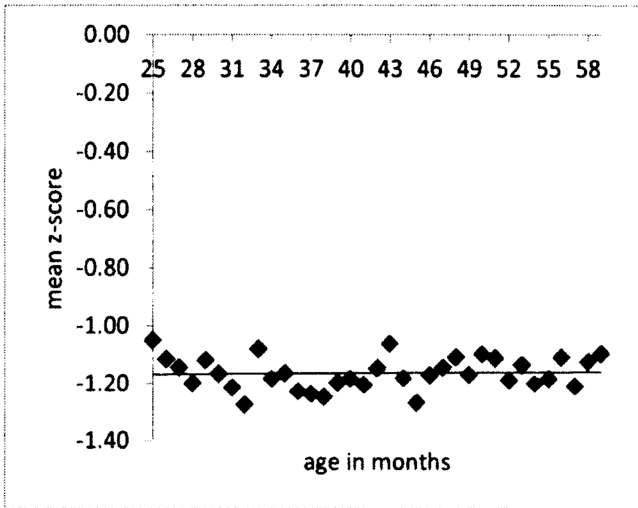
Source: Peruvian DHS data 2009-2012

Figure 3.6-Trend and line of mean height for age z-score by children's between 6 and 24 months old



Source: Peruvian DHS data 2009-2012

Figure 3.7-Trend and line of mean height for age z-score by children's after 24 and before 60 months old



Source: Peruvian DHS data 2009-2012

Therefore, I focus the analysis on the following two groups: i) children between 6 and 24 months of age, and ii) children older than 24 months but under five years of age. So for the first group of children, the experience is stunting and for those older than 24 months old is being stunted (UNICEF, 2013). This is an important point because for the first group we need interventions to prevent stunting but for the second group we can only consider palliative interventions.

Therefore, I run two multilevel models, the first one to analyse the determinants that are significant when the children are between 6 and 24 months old, the intention being to identify the significant predictor variables while the children are growing. In the second case the regression is for children older than 24 months of age but younger than five years old, when the status of stunted is already confirmed. The dependant variable is the z-score height for age according to the WHO child growth standards, as a continuous response variable for both cases. For the second group, I also consider logistic models where the dependent variable is a binary variable of stunted versus not stunted.

The first case can provide information to design interventions in order to prevent stunting and the second case may give additional information to mitigate the problem.

3.3.1.4 Multilevel Analysis

Multilevel models are a response to the need to analyze the relationship between individuals and the environment in which they operate (Victoria et al, 1997). Multilevel analysis handles data where observations are not independent, avoiding miss estimation of standard errors when using Ordinary Least Squares (OLS) regression. It must be taken into consideration that DHS data has hierarchical form, it collects information at cluster (PSU), household and individual levels. As a result, the observations are not independent (Rutstein & Rojas, 2006). As Marini & Gragnolaty (2006) observe:

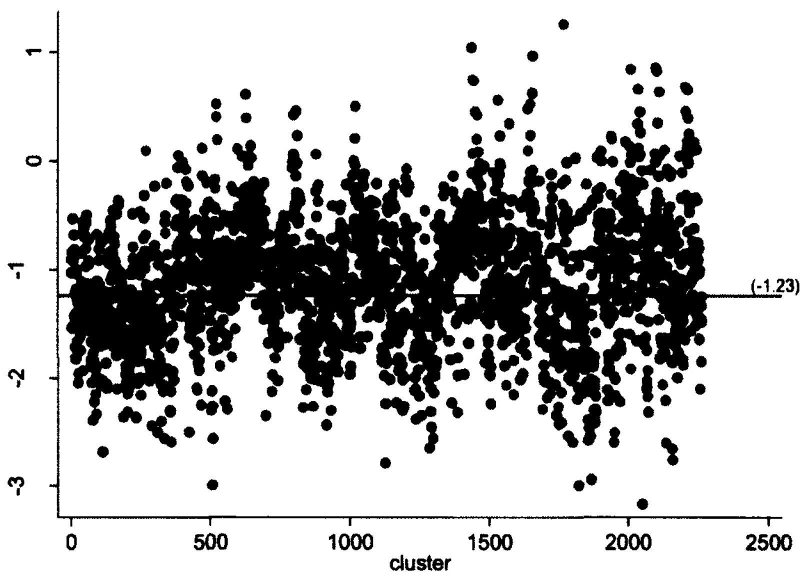
"One of the critical assumptions of OLS models is the independence of disturbance. But in cluster samples, such as our data, observations are not independent: the growth experience of children within the same community may be similar, especially if they come from the same family. OLS estimates of this type of data can therefore result in inefficient estimates of the parameters and underestimated standard errors. By ignoring the hierarchical structure of the data we are ignoring a significant and interesting community effect" (p. 5)

So, it is important to consider the hierarchical structure of DHS. By considering the different levels of the data correct estimates of coefficients and standard errors can be obtained, which help facilitate the exploration of variation between levels (Pérez, 2013).

As Figure 3.8 shows, the mean height-age z-score by community varies substantially across communities (clusters), suggesting an interesting community effect.

Multilevel models are applied to control for unobserved heterogeneity of clusters and to increase the precision of estimated coefficients of covariates. Mazumbar (2012) observes that "researchers have adopted fixed effects models to estimate nutrition models and control for unobservable variables at the cluster level, which leads to the difficulty that if the fixed effect is differenced away, then the effect of those variables that do not vary in a cluster will be lost in the estimation process. The variance-component model corrects for the problem of correlated observations in a cluster, by introducing a random effect at each cluster. In other words, subjects within the same cluster are allowed to have a shared random intercept" (p. 4).

Figure 3.8– Scatter of cluster mean of height for age z-score against clusters[16]



Source: Peruvian DHS data 2009-2012

In order to solve the problem of correlated observations, I am following the models developed by Gräb, (2009), Rabe-Hesketh & Skrondal (2012) and Mazumdar (2012). Using a linear three level

[16] I follow the steps in Marini & Gragnolaty (2006) in order to analyse the hierarchical structure of the data.

regression model for the two selected age groups, and a binary three level regression model for the group of children above 24 months old, where household and community (cluster) effects are controlled and also considers random effects. The linear three level regression model with random effects is as the following:

$$z_{ijk} = (\beta' x_{ijk}) + (v_k + u_{jk} + \varepsilon_{ijk}) \qquad (3.1)$$

With i=1, ...I identifies the individuals, j=1, ...J identifies the households and k=1, ...K identifies the communities (clusters).

z_{ijk} is the height for age z-score for the ith child from the *j*th household in the *k*th community. μ_{jk} is the household random effect, v_k is the community random effect and ε_{ijk} is the individual error. β is a vector of regression coefficients corresponding to the effects of fixed covariates. χ_{ijk} is the vector of observed covariates of the three levels (child, household, community). The error terms v_K, μ_{jk} and ε_{ijk} are assumed to be normally distributed with zero mean and variances σ_k^2, σ_h^2, σ_i^2, respectively.

The three-level random effect binary regression for children between 25 and 59 months old is especified as the following:

$$s_{ijk}^{*} = \left(\beta' x_{ijk}\right) + (v_k + \mu_{jk} + \varepsilon_{ijk}) \qquad (3.2)$$

$$s_{ijk} = \begin{cases} 1 \; if \; s_{ijk}^{*} > 0 \\ 0 \; otherwise \end{cases}$$

The indices i, j and k are defined as before. $s^{*}{}_{ijk}$ is the probability that child i in the household j in the community k is stunted. As before, β is a vector of regression coefficients corresponding to the effects of fixed covariates. χ_{ijk} is the vector of observed covariates of the three levels (child, household, community).The error terms v_{κ}, μ_{jk} and ε_{ijk} are assumed to be normally distributed with zero mean and variances σ_k^2, σ_h^2, σ_i^2, respectively.

It should be pointed out that for the group of children aged 6 to 24 months old, the main aim of the analysis is to identify the determinants that affect children's trajectory of growth and the risk of stunting. To this end, I consider four models that are labeled as Model 1A, Model 1B, Model 2A and Model 2B. Models 1A and 1B are the conventional OLS regression models, and the Models 2A and 2B are multilevel linear regression models. The B models are equivalent to the A models, but they do not include the dietary intake variable among the covariates. Doing so increases the number of observations for estimating the former models as there are a large number of missing data for dietary intake variable.

For the age group between 25 and 59 months old I estimated 6 models. Four of the models are as the same models as for the younger group. These models are labeled as Model 3A, 3B, 4A and 4B. As I previously stated, for children older than 24 months old growth status of the children could be identified as "stunted" versus non-stunted. So, I consider two additional logistic Models labeled as 5A and 5B. Both models regress a binary variable (stunted vs not stunted) on the set of regressions in previous models. Model 5B is distinguished from Model 5A by not including the dietary intake variable among the regressions. The models are estimated using the "xtmixed" command and the likelihood-ratio test is performed by using "lrtest" for the linear multilevel analysis models and "xtmelogit" command for the binary multilevel analysis models in Stata 12.

The estimated results for the above models are reported and discussed in the next chapter.

Chapter 4: Results and Discussion

The estimation results for Models 1A, 1B, 2A and 2B regarding the age group 6-24 months are reported first. Next, I report the results for Models 3A, 3B, 4A and 4B for the age group 25-59 months old. I discuss the regressions results for the multilevel models as they are preferred over the OLS results based on Likelihood Ratio Tests. Finally I report the results for the binary multilevel regressions Model 5A and Model 5B.

4.1 Estimation Results for the age group between six to twenty four months old

The estimated results for the age group 6-24 months old are reported in Table 4.1 for the Models 1A, 1B, 2A and 2B, respectively. As Table 4.1 shows, the OLS and multilevel results are strikingly similar for both A and B versions. However, the Likelihood Rate tests indicate clearly that the multilevel model (2A and 2B) are better-fitting models, compared to the OLS models (1A and 1B). Therefore, I discuss the estimated results from the multilevel models in the following.

Of the individual level variables age, gender, low birth weight and acute diarrheal disease are statistically significant at either 1% or 5%. For this age group, growth worsens with age as reflected in the negative coefficient of age. A month increase in the age of child, reduces the height for age z-score (HAZ) by roughly 0.03. The positive coefficient of female gender indicates that being a female improves HAZ by female gender indicates that being female improves HAZ by roughly 0.19 compared to males. Moreover, having low birth weight reduces HAZ by 0.68. And finally, acute diarrheal disease reduces HAZ by 0.07 to 0.08.

Wealth Index and mother's education as the two variables at the household level, are both significant at 1%. The estimated coefficients are positive, indicating that a higher level of wealth effect consistently increases in magnitude as we get to higher wealth quintiles.

Of the variables at the community (cluster) level, lack of access to delivery and access to antenatal services are significant at 1%. As showing in table 4.1, lack ok access to antenatal care is positively associated with HAZ. The findings show that children living in mountain areas (high elevation) have roughly 0.47 lower HAZ scores compared to Metropolitan area of Lima.

Finally, the random effect are estimated for three levels. The individual effect is roughly four time as large the household and community effects.

Age is a strong predictor, a finding that is consistent with the literature, where age was pointed out as a relevant factor for intervention, suggesting an interval before and after twenty four months old (Fenske et al, 2013; Bryce et al., 2008). About the positive association with female children, Gräb (2009) also find that the HAZ values are significantly better for girls than for boys. The finding that children whose mothers complete the primary studies or have a higher education level have better growth trajectory is also consistent with the finding by Smith & Haddad, (2000). Low Birth Weight has a negative association with HAZ, so children below two and a half kilograms at birth have worse results. This finding is similar to the findings in Adair & Guilkey (1997) and Medhin et al. (2010).

Living in rural areas is not related to HAZ, but living in the mountain range or in the Andes is negatively associated to the growth of the Peruvian children, indicating lower growth values for HAZ. All the investigations for Peru take into account where the children are living, in a similar way Marini & Gragnolaty (2006) and Sobrino et al (2014) find that there is not significant association between urban or rural areas with HAZ, but there is a negative and strong association with the Andes and the altitude of the area.

Moreover, the clear linkage of economic status with HAZ is evident, children from the richer economic classes show a better height for age indicator than the children from poorer economic status as seen from the regression coefficients on the wealth index variable. Looking at children health status, acute respiratory infection does not have an impact on the height status, nevertheless the opposite happens with acute diarrheal disease. Families with lack of access to main services, antenatal care and delivery service show significant impact, the rest of them such as growing control, access to water, safe water and sanitation are not showing any significant effect. However, these results must be taken cautiously because services and their success can be related to many factors, such as their design or implementation. Also, the literature shows a significant relationship between water and sanitation with diarrhea but not necessarily with CU. So, it is possible that the effects of water and sanitation are captured by the variable diarrhea (UNICEF, 2009).

There is no association between HAZ and any of the dummy variables of birth cohorts (2009-2011) for this group of age. As I mentioned I incorporated those variables in order to test the potential effects of the implementation of the ANP program in Peru that started in 2008, with the main objective to reduce CU in Peruvian children under five years old.

Table 4.1- Determinants of growth (stunting) for children between six and twenty-four months old

	Model 1A (OLS)	Model 2A (Multilevel)	Model 1B (OLS)	Model 2B (Multilevel)
Individual Variables				
Age of children (in months)	-0.0275***	-0.0272***	-0.0304***	-0.0303***
	(0.00289)	(0.00288)	(0.00236)	(0.00234)
Female	0.184***	0.187***	0.192***	0.192***
	(0.0228)	(0.0226)	(0.0198)	(0.0190)
Birth's Cohort (base cohort 2008)				
Cohort 2007			-0.0598	-0.0600
			(0.0436)	(0.0432)
Cohort 2009	-0.0513	-0.0335	-0.0181	-0.00744
	(0.0425)	(0.0426)	(0.0285)	(0.0288)
Cohort 2010	-0.0211	0.000646	0.00153	0.0139
	(0.0427)	(0.0431)	(0.0287)	(0.0292)
Cohort 2011	0.00444	0.0219	0.0174	0.0225
	(0.0470)	(0.0474)	(0.0322)	(0.0322)
Cohort 2012	0.0729	0.101	0.0483	0.0674
	(0.0788)	(0.0789)	(0.0656)	(0.0655)
Weight at birth; below 2.5 kg	-0.686***	-0.679***	-0.696***	-0.686***
	(0.0465)	(0.0459)	(0.0400)	(0.0396)
Poor Health Status				
Acute Respiratory Infection	-0.0190	-0.0160	-0.0108	-0.00605
	(0.0297)	(0.0294)	(0.0257)	(0.0255)
Acute Diarrheal Disease	-0.0778***	-0.0724***	-0.0871***	-0.0842***
	(0.0279)	(0.0277)	(0.0241)	(0.0239)
Dietary intake	0.00272	-0.00101		
	(0.0286)	(0.0285)		
Household Variables				
Wealth index: (base poorest quintile)				
2nd quintile	0.260***	0.245***	0.264***	0.254***
	(0.0357)	(0.0363)	(0.0308)	(0.0313)
Middle quintile	0.414***	0.390***	0.449***	0.435***
	(0.0473)	(0.0465)	(0.0391)	(0.0398)
4th quintile	0.579***	0.547***	0.610***	0.589***
	(0.0553)	(0.0561)	(0.0477)	(0.0484)
Richest quintile	0.793***	0.756***	0.843***	0.812***
	(0.0638)	(0.0648)	(0.0555)	(0.0565)
Mother's education (base: no education or primary education)	0.218***	0.216***	0.178***	0.177***
	(0.0286)	(0.0285)	(0.0247)	(0.0246)
Community Characteristics				
Water and sanitation services				
No access to piped water inside	0.0000111	-0.00803	0.0186	0.00924
	(0.0279)	(0.0287)	(0.0242)	(0.0249)
No access to improved sanitation	-0.0199	-0.0226	-0.00279	0.000952
	(0.0289)	(0.0291)	(0.0251)	(0.0254)
No access to treated water	0.00879	0.00546	-0.0211	-0.0231
	(0.0293)	(0.0296)	(0.0249)	(0.0252)
Health services				
No access to delivery service	-0.134***	-0.128***	-0.127***	-0.118***

	(0.0365)	(0.0369)	(0.0313)	(0.0317)
Access to growing control	-0.0458	-0.0409	-0.0340	-0.0241
	(0.0371)	(0.0371)	(0.0354)	(0.0353)
Access to vaccination	-0.0468*	-0.0441	-0.0453*	-0.0483*
	(0.0278)	(0.0276)	(0.0243)	(0.0241)
Access to antenatal care	0.144***	0.145***	0.150***	0.149***
	(0.0313)	(0.0310)	(0.0269)	(0.0267)
Place of residence (base: urban); rural	0.00517	-0.000265	0.0223	0.0187
	(0.0334)	(0.0361)	(0.0287)	(0.0311)
Natural Region (base: Lima Metropolitana)				
Rest of the Coast (no Lima Metropolitana)	0.00443	0.00332	0.0340	0.0340
	(0.0467)	(0.0497)	(0.0415)	(0.0439)
Mountain Range	-0.438***	-0.446***	-0.437***	-0.446***
	(0.0486)	(0.0519)	(0.0432)	(0.0461)
Jungle	-0.0501	-0.0624	-0.0296	-0.0459
	(0.0504)	(0.0537)	(0.0446)	(0.0473)
Constant	-1.068***	-1.063***	-1.082***	-1.074***
	(0.111)	(0.112)	(0.0883)	(0.0896)
Random Effects				
Cluster random effect		.2794418		.2706248
Household Random effect		.2417981		.2720544
Individual Random effect	.9821041	.9099909	1.005086	.928615
Observations				
Children	7 460	7 460	10 352	10 352
Households		7 322		10 112
Clusters		2 027		2 161
Adj-R2	0.2174		0.2138	
Integrated log Likelihood	-10450.569	-10407.06	-14741.37	-14676.661
LR-Test chi1(2)		87.02		128.32
Prob > chi2		0.0000		0.0000

Standard errors are given in the parentheses
Note: Labels ***, **, and * indicate significance at 1%, 5% and 10%, respectively.

4.2 Estimation Results for the age group between 25 to 59 months old

The analysis of the determinants of CU in children 25 to 59 months old consists of four linear models and two logistic regression models that are dreported and discussed in the next section. Models 3A and 3B are OLS regressions (with and without dietary intake, respectively), and the Models 4A and 4B are the multilevel linear regressions (with and without dietary intake, respectively). I discuss the regression results for the multilevel models as they are preferred over the OLS results bases on likelihood ratio tests. As I previously pointed out, the Models B do not take into account the variable dietary intake, and the number of observations is increased. However, for this group of age dietary intake is significant at 10% of significance, but there are no major differences in the effects for the other explanatory variables.

Similar to the results for the age group 06-24 months old, the research findings for the age group 25-59 months old are in line with those found in the literature. First of all, there is a significant association between child growth and gender. Female children show better growth than males. This finding confirms the resuly by Ravina & Chávez (2007). Secondly, child growth is negatively associated with LBW. That is, children born with a weight less than 2.5 kg have lower growth . Medhin et al. (2010) concluded for developing countries that LBW is a factor associated with a risk of being stunted.

The age for Peruvian children above twenty four months old is not significantly related to child growth, a conclusion in line with the findings in in Fenske et al (2013) and Bryce et al (2008), that the status of stunted can be determined after twenty four months old and after this point the status is irreversible.

Furthermore, in the present case, the dietary intake variable shows a certain association at 10% level of significance, so Peruvian children with access to less than four kind of foods present worse growth outcomes, or are more prone to suffer from CU. Also, in this case not only living in a mountain range (Andes region) shows negative effect but also living in a rural zone and jungle region have a significant negative effect similar to the conclusions in Arocena (2014). Children who live in rural areas and in mountain range have lower growth. Moreover, similar to the case of children between 6 to 24 months old, the higher wealth and educational attainment of the mother, the better the height-for-age z-scores for the child.

About health variables, diarrhea shows a negative effect at 1% level of significance, respiratory infeccions still has no effect. Among all community variable services lack of access to delivery services and antenatal care show a significant negative effect on height for age.

In contrast to the results of Models 2A and 2B, the cohorts 2009 and 2010 are associated with child growth in Models 4A and 4B at significance level of 1% and 10% , respectively.. This implies a positive effect for the ANP program, which is consistent with the findings of Cruzado (2012) for 2009.

Table 4.2- Determinants of Stunted for children between twenty five months old and before fifty nine months old

	Model 3A (OLS)	Model 4A (Multilevel)	Model 3B (OLS)	Model 4B (Multilevel)
Fixed Effects				
Individual Variables				
Age of children (in months)	0.00357	0.00334	0.0000153	-0.000393
	(0.00489)	(0.00488)	(0.00436)	(0.00434)
Female	0.125***	0.124***	0.100***	0.1000***
	(0.0292)	(0.0291)	(0.0262)	(0.0262)
Birth's Cohort (base cohort 2008)				
Cohort 2006			-0.0256	-0.0339
			(0.0484)	(0.0489)
Cohort 2007	0.0243	0.0222	0.0263	0.0212
	(0.0498)	(0.0501)	(0.0384)	(0.0390)
Cohort 2009	0.0988***	0.0987***	0.0936**	0.0953**
	(0.0355)	(0.0356)	(0.0365)	(0.0365)
Cohort 2010	0.0728~	0.0725~	0.0721~	0.0689~
	(0.0425)	(0.0428)	(0.0434)	(0.0438)
Weight at birth; below 2.5 kg	-0.455***	-0.442***	-0.454***	-0.441***
	(0.0543)	(0.0541)	(0.0485)	(0.0482)
Poor Health Status				
Acute Respiratory Infection	-0.00485	-0.00710	-0.00541	-0.00867
	(0.0403)	(0.0403)	(0.0360)	(0.0360)
Acute Diarrheal Disease	-0.0910**	-0.0916**	-0.101***	-0.0996***
	(0.0411)	(0.0411)	(0.0370)	(0.0370)
Dietary intake	-0.0837*	-0.0802*		
	(0.0438)	(0.0438)		
Household Variables				
Wealth index: (base poorest quintile)				
2nd quintile	0.250***	0.244***	0.258***	0.247***
	(0.0473)	(0.0477)	(0.0419)	(0.0424)
Middle quintile	0.489***	0.483***	0.564***	0.556***
	(0.0596)	(0.0602)	(0.0524)	(0.0530)

4th quintile	0.751***	0.745***	0.817***	0.805***
	(0.0709)	(0.0714)	(0.0629)	(0.0635)
Richest quintile	1.104***	1.091***	1.167***	1.145***
	(0.0820)	(0.0826)	(0.0733)	(0.0740)
Mother's education (base: no education or primary education)	0.286***	0.283***	0.317***	0.311***
	(0.0372)	(0.0372)	(0.0332)	(0.0332)
Community Characteristics				
Water and sanitation services				
No access to piped water inside	-0.0266	-0.0258	-0.00164	-0.00144
	(0.0359)	(0.0363)	(0.0324)	(0.0329)
No access to improved sanitation	-0.00462	-0.00480	0.0161	0.0170
	(0.0366)	(0.0368)	(0.0329)	(0.0331)
No access to treated water	-0.00158	0.000758	-0.0203	-0.0149
	(0.0369)	(0.0372)	(0.0328)	(0.0330)
Health services				
No access to delivery service	-0.240***	-0.237***	-0.215***	-0.208***
	(0.0463)	(0.0464)	(0.0408)	(0.0409)
Access to growing control	0.0646	0.0650	0.0498	0.0552
	(0.0486)	(0.0489)	(0.0487)	(0.0490)
Access to vaccination	-0.000336	-0.000662	0.00695	0.00286
	(0.0331)	(0.0331)	(0.0289)	(0.0289)
Access to antenatal care	0.0770*	0.0789*	0.0695*	0.0713*
	(0.0419)	(0.0417)	(0.0366)	(0.0364)
Place of residence (base: urban); rural	0.0921**	0.0815*	0.0831**	0.0672*
	(0.0423)	(0.0433)	(0.0377)	(0.0392)
Natural Region (base: Lima Metropolitana)				
Rest of the Coast (no Lima Metropolitana)	-0.0336	-0.0311	0.0158	0.0163
	(0.0596)	(0.0609)	(0.0539)	(0.0556)
Mountain Range	-0.465***	-0.465***	-0.433***	-0.437***
	(0.0625)	(0.0638)	(0.0563)	(0.0582)
Jungle	-0.170***	-0.173***	-0.142**	-0.150**
	(0.0645)	(0.0658)	(0.0581)	(0.0600)
Constant	-1.778***	-1.761***	-1.754***	-1.724***
	(0.181)	(0.181)	(0.163)	(0.163)
Random Effects				
Cluster random effect		.1878704		.2355158
Household Random effect		0.0000000977		0.000000286
Individual Random effect	.9120393	.8925512		.9100064
Observations				
Children	3 947	3 947	5 168	5 168
Households		3 911		5 118
Clusters		1 705		1 901
Adj- R2	0.2753		0.2773	
Integrated log Likelihood	-5237.1415	-5233.6841	-7012.4087	-7000.7399
LR-Test chi1(2)		6.91		23.34
Prob > chi2		0.0315		0.0000

Standard errors are given in the parentheses

Note: Labels ***, **, and * indicate significance at 1%, 5% and 10%, respectively.

4.3 Logistic Regression Results for the age group between 25 to 59 months old

I also attempted two logistic multilevel effects regression models (Model 5A and Model 5B, with and without dietary intake, respectively). Here the dependent variable is the stunting status status represented by a dummy variable (0,1). The results are presented below in the table 4.3.

Table 4.3- Determinants of Stunted for children between twenty five months old and before fifty nine months old: Logistic multilevel effects regression models

	Model 5A		Model 5B	
	Odds Ratio SE	95% Conf. Interval	Odds Ratio SE	95% Conf. Interval
Individual Variables				
Age of children (in months)	0.9796743 (.0147096)	[0.9512642 1.008933]	0.988712 (.0126748)	[0.9641794 1.013869]
Female	0.6755059*** (.0607588)	[0.5663271 0.8057326]	0.7309028*** (0.056691)	[0.6278239 0.8509055]
Birth's Cohort (base cohort 2008)				
Cohort 2006			1.352473** (0.1781923)	[1.044673 1.750963]
Cohort 2007	0.0607588 (0.1574738)	[0.7948756 1.420876]	1.265629** (0.1243863)	[1.043879 1.534485]
Cohort 2009	0.7584419** (0.0830522)	[0.6119453 0.9400089]	0.7584419 (0.1099659)	[0.7245781 1.208286]
Cohort 2010	0.8066582~ (0.1044156)	[0.7281375 1.214094]	0.93902 (0.1102898)	[0.7459325 1.182089]
Weight at birth; below 2.5 kg	2.264197*** (0.3233237)	[1.711449 2.995466]	2.222979*** (0.2764932)	[1.742061 2.836661]
Poor Health Status				
Acute Respiratory Infection	0.9296485 (0.1137503)	[0.7314205 1.1816]	1.015322 (0.1045123)	[0.8298225 1.242288]
Acute Diarrheal Disease	1.248368 (0.147947)	[0.9896117 1.574782]	1.240343 (0.1284364)	[0.012513 1.519438]
Dietary intake	1.197225 (0.1405168)	[0.9511991 1.506886]		
Household Variables				
Wealth index: (base poorest				

quintile)				
2nd quintile	0.818893 (0.100928)	[0.6431572 1.042647]	0.7482245** (0.0786399)	[0.6089322 0.9193798]
Middle quintile	0.4513268***(0.0788121)	[0.3205173 0.6355222]	0.3858476*** (0.0571959)	[0.2885616 0.5159327]
4th quintile	0.2536122***(0.0615153)	[0.1576542 0.4079759]	0.2249381*** (0.0465418)	[0.1499483 0.3374306]
Richest quintile	0.1204824*** (0.0468725)	[0.0562046 0.2582709]	0.1069198*** (0.0359962)	[0.0552698 0.206837]
Mother's education (base: no education or primary education)	0.5412498*** (0.055499)	[0.4427074 0.6617268]	0.4960094*** (0.0434878)	[0.4176961 0.5890055]
Community Characteristics				
Water and sanitation services				
No access to piped water inside	1.225522** (0.1266217)	[1.000863 1.50061]	1.167338 (0.1050695)	[0.9785472 1.392552]
No access to improved sanitation	1.053976 (0.1145911)	[0.8516982 1.304294]	0.9692237 (0.0916721)	[0.8052205 1.16663]
No access to treated water	1.052142 (0.1144289)	[0.8501574 1.302115]	0.9912957 (0.0926321)	[0.8253959 1.190541]
Health services				
No access to delivery service	1.799275*** (0.2135659)	[1.425817 2.270552]	1.704981*** (0.1725357)	[1.398241 2.079012]
Access to growing control	0.9402612 (0.1263357)	[0.7225685 1.223539]	0.9820016 (0.1279954)	[0.7606161 1.267824]
Access to vaccination	0.8314125* (0.0850565)	[0.6803549 1.016009]	0.8591958* (0.0734226)	[0.7266958 1.015855]
Access to antenatal care	0.8455382 (0.0984465)	[0.6730191 1.06228]	0.8677474 (0.0861119)	[0.7143702 1.054055]
Place of residence (base: urban); rural	0.8491955 (0.103973)	[0.6680194 1.079509]	0.8922567 (0.0943785)	[0.7251935 1.097806]
Natural Region (base: Lima Metropolitana)				
Rest of the Coast (no Lima Metropolitana)	0.8991498 (0.2479523)	[0.5237234 1.543697]	0.9044206 (0.2156751)	[0.5667432 1.443293]
Mountain Range	2.337663*** (0.6312555)	[1.376975 3.968603]	2.269244*** (0.5295847)	[1.436256 3.585339]
Jungle	1.363991 (0.3748772)	[0.7959188 2.337515]	1.394607 (0.331687)	[0.8749954 2.222786]

Constant	0.8670675 (0.4969236) [0.2819826 2.666144]	0.6411708 (0.3145415) [0.2451301 1.677069]
Observations		
Children	3 940	5 154
Households	3 904	5 104
Clusters	1 704	1 899
Integrated log Likelihood	-1663.8472	-2225.3496
Integrated log Likelihood	1.45	3.40
LR-Test chi1(2)	0.4836	0.1829

Standard errors are given in the parentheses
Note: Labels ***, **, and * indicate significance at 1%, 5% and 10%, respectively.

Generally, the results are largely similar to the finding from the Models 3A and 3B, thus, male Peruvian children are more vulnerable to stunting compared to females, children with LBW have more probability of stunting, as well as children from poor households, with no educated mother, with no access a health services delivery services, or living in the mountain range.

The Odd Ratio (OR) of stunting in girls was 0.73 relative to boys. Also, children who settled in mountain range were significantly more likely to be stunted as compared to those of Metropolitan area of Lima (OR= 2.22). Higher wealth status of the family was determined as the protective factor of stunting. Children from families in the richest quintile were significantly less likely to be stunted compared to those with a poorer wealth status (OR=0.11 to 0.12). UNICEF (2013) points out that poor families have limited access to healthy and varied diets, health care, clean water or basic sanitation.

Moreover, lack of piped water was another predictor of stunting (OR= 1.22). According to UNICEF (2009), the access a safe water have an impact on CU but that impact will be higher if there is a mixed policy about sanitation, concealing to families and improved sanitation services. It is important to note that there are higher probability of being stunted for children who were born in 2006 (cohort 2006 – OR=1.35) and 2007 (cohort 2007 –OR=1.26) suggesting an improvement over time, which may partly be related to the effect of the APN program.

Overall, the results are consistent with the findings from the literature and with the conceptual framework of CU (Figure 3.2). Although not all the variables have been found to be significant, several variables at individual, household and community levels are identified as important determinants or factors associated with the child growth.

Chapter 5: Conclusions

This thesis applies the UNICEF's (1990) malnutrition framework adapted by Tufts University (2001) for stunting in the Peruvian context. By using multilevel modelling, I analyze the determinants of CU for two group of children, those between 6 and 24 months old and those who are older than 24 months but not younger than 59 months old.

The purpose of this chapter is to summarize the main findings of this thesis and highlight the contributions of this investigation. Thus, in the first section, I summarize the main findings from the models as relate them to the literature. In the second section, I discuss the thesis policy implications. I also recognize some of the study's limitations and briefly suggest areas of further research that could contribute to a better understanding of stunting in Peru as basis for effective interventions to reduce stunting.

5.1 Summary of Main Findings

In this study, the CU status was analyzed based on the modified UNICEF (1990) malnutrition framework by Tufts University (2001). The framework recognizes that CU has many possible causes and that solving malnutrition problems requires an understanding of the importance of various determinants at different levels.

Therefore, I use a multilevel modeling techniques that allow for the estimation of different level effects for two group of ages, which enables us to separate effects working at the individual, household and community level. The patterns of association with the outcome of interest (height for age z-score - HAZ) was analyzed for the two groups of age: children from 6 to 24 months old and children from 25 to 59 months old, I also considered a binary logistic multilevel model for the older group.

The main motivation for using a multilevel analysis stemmed from the hierarchically nature of the DHS data, where children are nested into households, households nested into PSU's, and PSU's into the communities. The findings for the two group of age provide enough information to answer the three questions I posed at the beginning:

1. What factors can explain CU in children aged six to fifty nine months in Peru?

The findings for the two groups of age (As reported in tables 4.1, 4.2 and 4.3) demonstrate that there are different factors at individual, household and community level that explain CU in Peruvian children from 6 to 59 months old. At the individual level for both age groups demonstrated child's gender, the occurrence of diarrhea and LBW are risk factors for stunting.

The results show lower probability of stunting in female children compared to male children. A result consistent with that of Ravina & Chávez (2007), but not with those of Marini & Gragnolaty (2006) and Gutierrez et al (2014) for Peruvian children.

The occurrence of diarrhea was found to be significantly associated with height for age z-score. In contrast, the respiratory infections did not show any effect on the growth z-score. This negative effect of diarrhea but not of respiratory infections, is consistent with other studies (Adair & Guilkey, 1997; Checkley, et al, 2002).

In addition, LBW is find to have a significant association with stunting, this has also been documented in previous investigations (Adair & Guilkey, 1997; Ngoc & Kam, 2008; Medhin, et al., 2010). No previous research has analyzed the effect of LBW on children in Peru. Such findings supports the importance of prenatal caring and the access to services that it is also significant for children between 6 to 24 months.

At the household level, the mother education is positively associated with child's growth. Such findings are in line with those of Marini & Gragnolaty (2006) for Peruvian children and Smith & Haddad (2014) for children in developing countries. As educated mothers have enough knowledge about their children's health and nutrition, the nutritional status of children can be developed through improvement of child care, health services usage, hygiene and sanitation, etc. (Baldárrago, 2010).

Also, the wealth index is a strong predictor of child growth. Children from richer households have better results on their CU status. For the group between 25 to 59 months old, the odd ratios (Table 4.3) indicate that as a more household cumulative living standard (better wealth index position) a lower risk to be stunted. This significant association may be due to high quality of life, giving essential health services and also adequate dietary intake. Moreover, low literacy and low purchasing capacity, and also poor sanitation and hygiene are common results of poverty inequality (Javenic et al, 2010).

At community level, the children from the mountain range have worse height for age z-score results. This findings echoes those of Arocena (2010) and Marini & Gragnolaty (2006) for the impact of geographic altitude of Peruvian regions on stunting. I do not find a significant association between rural areas and stunting. The high prevalence of stunting in rural areas in Peru may be result of low educational level, low wealth status, poor water supply, and high incidence of infectionus disease. It is possible that the rural effects, are captured by those factors. This possibility is also demostrated by Ngoc & Kam (2008) for Vietnam.

Also there is a significant association of access to health services, such as the delivery and antenatal services with CU status. However, access to water and sanitation services are not associated with stunting, this is also summarized in the findings of UNICEF (2009) and in Esrey (1996). As for the Peruvian investigations only Ravina & Chavez (2009) and Gutierrez et al. (2014) found a correlation between stunting in children and access to sanitation. Those services are important to prevent diarrhea cases and depend on a combination of services like improved sanitation, treated water at the point of use and handwashing practices (UNICEF, 2009). This mixed results in this case indicate that further investigation is needed.

2. Do the same factors that affect Peruvian children during the window of opportunity of intervention (before two years old) also act in children above two years old?

This question was inspired by the UNICEF (2009) and Bhutta et al (2013) recommendations for an early intervention policy to prevent undernutrition during the critical window of opportunity that is during the pregnancy of the mother and during the two years of life of a child.

As expected, age is associated with stunting for the younger group of children (6-24 months), but not for the older group (25-59 months). Such finding confirm the critical role of age for stunting during the first two years of life. The investigations in Peru did not consider the critical role of younger age into their analysis. For example, Ravina & Chavez (2009), Marini & Gragnolaty (2006) and Gutierrez et al. (2014) did not differentiate between age groups before and after 24 months old. They all find that age is significant for stunting. This leaves the question of intervention open to the first five years old as opposed to first two years which may be too risky. Other difference between the two groups of age is the level of significance of dietary intake, not having more than at least four kinds of food per day shows a negative association only for the case of children above twenty four months old. Bhutta et al., (2013) conclude that dietary diversification strategies have not been proven to affect nutritional status, however the access is still an important factor. I think this is an aspect that needs more research. I cannot find any investigation that linked that factor exclusive to stunting. Some of them analyze the effects of the early introduction of dietary intake, breastfeeding and stunting (Chung, et al., 2007). Therefore, I think it is important to complement the analysis with other variables, such as breastfeeding and health status of children.

3. Is ANP affecting CU in Peruvian children?

I do not find a strong association between the birth cohorts and stunting for the age group between 6 to 24 months. However, I do find a signifficant association for the group older than 24 months. This implies that the ANP program may have affected the cohorts of children after 2008. Interestingly, the binary multilevel regression reveals that children who belong to the birth's cohorts before 2008 have higher risk to be stunted. Cruzado (2012), whose research was the only one that took into account the ANP program,found a positive effect for the year 2009. ANP program as a public policy needs further investigation in order to find out which of its many interventions is the most effective one.

5.2 Policy Implications, Limitations and Further Studies

5.2.1 Policy Implications

The findings of my thesis have important implications for the development of policy interventions by the Peruvian Government for controlling and reducing CU. My findings can inform policy implementation such as BfR nd the ANP program, which is a multi-sector effort with a preventive approach to reduce CU. Specifically, my results for children between 25 to 59 months old show that ANP program can be effective in reducing the prevalence of stunting.

Given that age is a signifiant variable linked to height for age z-score only for children between 6 to 24 months old, it is very important to intervene in a timely fashion. Morre importantly, since lack of access to nutrition, clean water and sanitation, health care servies and adequate income are routed in poverty and inequality, a general policy targeted at poverty eradication and inequality reduction could go along way in improving the prospect of healthly child growth.

For example, antenatal care and access to delivery services have a possitive association with CU. Also, low birth weight is a strong predictor of stunting and stunted. Investing in interventions that prevent low birth weight through the antenatal care, access access to delivery and adequate health services is an important aspect to be considered in APN program.

The causes of stunting are complex and difficult to measure in any cross-sectional survey. Although the dataset was not ideally suitable for the use of conceptual framework to analyze the causes of stunting, some interesting associations between CU and determinants at the individual, household and communities levels are identified. To repeat, the maternal level of education, gender, place of residence, wealth status, child's health status, and access to some services, are found to be important in determining the generation of CU the two age groups.

5.2.2 Limitations

One of the limitations of the study is that the analysis is based on cross-sectional data, thus I cannot discuss causalities in my conclusions. It could have been preferred if the data were panel so that the trajectory of stunting over time, and the causal dynamics of the determinants could be better examined. Following a child during his or her growing process would make it easier to account for the effect of unobservable health determinants, and also to capture the time dynamics of the relationships between growth determinants.

Also, the characteristic of the survey might have affected the findings. As the survey is questionnaire-based, questions that required a good memory were vulnerable to recall bias.

Finally, there was no reliable variable to use for capturing the potential effects of the ANP policy. Using cohorts to measure such effects is less than satisfactory.

5.2.3 Future Studies

My study can be extended in several ways. For instance, considering cultural barriers such as those addressed by Gräb (2009) may shed light on the use of health services as related to child growth. Considering the quality of the services in addition to their quantity or availability is important. Moreover, examining the issues of poverty and inequality – as social determinants of health including healthy child growth – that underlie poor hygiene, food insecurity and lack of access to health care and education will improve our understanding of stunting in Peru.

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Appendix 1: List of Variables of Interest

Variables	Characteristics	Number of Observations	Name and type in the database
Stunting (Z-score height for age) Stunted	Height-for-age Z-score based on the new WHO child growth reference standards (WHO, 2006) Height-for-age Z-score: >-2 standard deviations (sd) (0), <-2 sd below the median height for age (1)	38 766 0= 28 721; 1=9 126	"Zoms_te" is provided in database; Continue Variable "CM_OMS1"; Dummy variable. It is created with the information of the binary variable "dc06" (Chronic Undernutrition according to the WHO 1:yes, 2:no); At the same time, that variable is created based on the variable "hv070": "height standard deviations according to WHO"
Individual variables Gender Age	 Whether the child is male (0) or female (1) Age of the children from 0 to 59 months old	 0=19 611; 1=19 155 38 766	 "Gender2" is created with the information of the variable "hc27" (1: male, 2: female); Dummy variable "hc1", continues variable. Based on the information of this variable it was also created "agegrp", it is categorical variable, with values 1: children of 0-5 months old, 2: children of 6-24 months old and children of

			25-59 months old. N: 1 – 3 340, 2 – 12 149, 3 – 23 277
Birth's Cohort	To identify in which cohort of birth the child was born.	Cohorts 2004 and 2005= 3 951 Cohort 2006=4 748 Cohort 2007=6 240 Cohort 2009=6 944 Cohort 2010=4 783 Cohort 2011=2 830 Cohort 2012=1 078	"coh200405", "coh2006", "coh2007" , "coh2008, "coh2009", "coh2010", "coh2011", "coh2012"; dummies variables. They were created based on the variable "cohort" by making a group of children according to the semester and year of birth.
Inadequate food intake -Access to variety of food	Whether the child after six months of age accesses more than 4 types of food in the last 7 days (0), less than 4 types of food in the last 7 days (1)	0= 9 665 1= 3 230	"divfood1"; dummy variable. To get this variable it was generated first the variable dietary diversity: "divfeed" 1: Less than 4 types of food; 2: More than 4 types of food. This categorical variable was created with the information of the following variables in the database that collect information of the following questions: do you feed your child in the last 7 days with? S496a (flour, bread, noodles, cookies), s496c (juice, pumpkin), s496e (beans, lentils, peas, soy), s496g (tubercle, root), s496i (vegetables), s496k (papaya, mango, among others), s496m (others fruits), s496o (meat: beef, chicken, fish), s496aa (cheese yogurt), s496ak (porridge from a social's program).

-Exclusive Breastfeeding	Whether the child has had exclusive breastfeeding during the first six months of its life (1) if not (0)	0=17 648 1=2 499	"breastfl", dummy variable. This variable was generated based on "lac_ex" that have the categorical values 1: breastfeeding and aged between 0-6 months old, 2: no breastfeeding or aged more than 6 months old. As well this variable was created with the combination of the variable age (hc1 was grouped for children between 0 and 6, and older), "m4", duration of breastfeeding – selecting for exclusive for 6 or more months of duration, "v404", currently breastfeeding – selecting as an exclusive if the child is more than 06 months old. Also the information from "v404" and "m4" was contrasted to the questions from v409 to v414 where the mothers were asked if they were feeding his/her child with other aliments like water, liquid, formula, among others.

Low birth weight	Whether the weight of the child at birth is more than 2.5 kilograms (0) or is less than 2.5 kilograms (1)	O=30 125 1=2 389	"birthweight1", dummy variable. It was created based on the variable "pesorn" 1: less than 2.5 kilograms, 2: more than or equal to 2.5 kilograms. This variable was based on "m19" original variable in the database with the information of the weight of the child at the moment of birth if the mother can remember.
Poor Health Status			
Diarrheal Disease	Whether the child has hadn't diarrhea in the last two weeks (0) or has had diarrhea in the last two weeks (1)	0=23 833 1= 4 658	"add1", dummy variable. Is was created based on the variable "eda" 1: yes 2: no. This variable was created based on the information of "h11": had diarrhea recently?
Acute respiratory infections	Whether the child has hadn't a cough in the last two weeks (0) or has had a cough in the last two weeks (1)	0=30 297 1=5 793	"ari1", dummy variable. It was created based on the information of "ira059" 1: yes, 2: no. This variable was created based on two variables "h31": had a cough in last two weeks, and "h31b": short, rapid breaths? For children only under 59 months old.
Household variables Women's education	Whether the mother has not education or she completed	0=14 661 1=22 667	"educ_mom2", dummy variable. This variable was created based

	primary school (0), and whether the mother completed secondary school or higher level of education (1)		on the variable "levmom_edu" 1: no education or primary education, 2: secondary or higher education. The information was provided by the variable "mhv106": level of the education of the mother.
Access to delivery services	Whether the mother has received delivery services 0; otherwise 1	0=25 359 1=6 298	"deliv2", dummy variable. This variable was created with the information of the following variables: "m3n": no assistance during delivery, "m3a': assistance by a doctor, "m3b: assistance by a nurse/midwife", "m3c": assistance by an obstetrician
Access to antenatal care	Whether the mother received antenatal care (at least 6 controls during pregnancy in a hospital, health center or post center) 1; otherwise 0	0=5 732 1=24 330	"cfantenatal", dummy variable. This variable was created with the information of two variables "m14": antenatal visits for pregnancy and the variables "m57i-m57q": antenatal care, kind of health center.

Household economic status	Wealth Index Score[17]: Whether the household is destitute, poor, middle status, or wealthy. The Wealth Index Score categorizes households into 5 wealth quintiles (between poor and wealth	Poorest: 12 533 Poorer: 10 594 Middle: 8 437 Richer: 5 547 Richest: 3 218	"quintiln1 – quintiln5", 5 dummies variables. These variables were created based on the wealth index provided by the survey "hv270"
Community variables Access to health services - Access to growth control services[18]	Whether the child has not received checkup growth control services – that it is according to the Peruvian Health Norm (at least 6 controls) 0; otherwise 1	0=34 710 1=2 136 0=12 768	"cred1", dummy variable. This variable was created based on "S466c": number of check-up growth controls.

[17] The wealth index is presented in the DHS Final Reports and survey datasets as a background characteristic. It is generated by the DHS program with principal components analysis and it categorizes households into 5 wealth quintiles. It is "a composite measure of a household's cumulative living standard. The wealth index is calculated using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities" (DHS Program, 2015; Rutsein & Johnson, 2004) .

[18] The growth control services is provided in a health center. Basically is a prevention activity comprised of growth monitoring (process of following the growth rate of a child in comparison to a standard by anthropometric measurements) linked with promotion and counseling about child growth; improves caring practices and serves as the core activity in an integrated children health and nutrition program. In the Peruvian case it is considered at least 11 controls during the first year of age (MINSA, 2011; Griffiths & Del Rosso, 2007).

- Access to immunizations services	Whether the child has not received the basic vaccines for his/her age according to the Peruvian Health Norm 0; otherwise 1	1=9 287	"vaccination1", dummy variable. This variable was created based on the variable provided by the survey: "vaccom". This variable was constructed with the information of the variables "s45d-s45v" whose cover the number, the types of vaccines and age of the child at which the vaccine was administered.
Access to water and sanitation services - Access to safe (treated) water	Whether the household has access to treated water at the point of use (0), otherwise (1)	0=28 218 1= 10 548	"safewat11", dummy variable. It was created based on the variables hv237: anything done to water to make safe to drink, hv237a: water usually treated by: boil, hv237b: water usually treated by: add bleach/chlorine, hv237e: water usually treated by: solar disinfection and hv237d: water usually treated by: use water filter)

- Access to water	Whether the household has accessed to piped water into the house (0), otherwise (1)	0=26 269 1= 12 497	"watacc1"; dummy variable. This variable was created with the information of the variable "hv201": source of drinking water; by taking only into consideration options 11 and 12: piped into dwelling and piped outside dwelling but within building.
- Access to improve sanitation	Whether the household has accessed to improved sanitation services (0), otherwise 1	0=16 216 1=22 550	"sanitation1", dummy variable. This variable was created with the information of the variables "hv225": hare toilet with other households and "hv205": type of toilet facility, by taking only into consideration options 11, 12, 21 and 22: inside dwelling, outside dwelling, ventilated latrine, septic well.
Area of residence	Whether if the cluster is in urban area (0) or in rural areas (1)	0=21 226 1=17 540	"area2", dummy variable. This variable was created based on "hv025" type of residence 1: urban, 2: rural

Place of residence	At what natural region of Peru the cluster is. Lima Metropolitana, rest of the coast area, mountain or Andes area and jungle area	Lima Metropolitana= 2 609 Rest of coast area= 9 236 Mountain or Andes area= 15 752 Jungle area= 11 159	"nat_region1", "nat_region2", "nat_region3", "nat_region4". They are 4 dummies variables created based on the information of "shregion".