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"Measuring early childhood health: a composite index comparing Colombian departments"

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Abstract

This paper presents a composite index of early childhood health using a multivariate statistical approach. The index shows how child health varies across Colombian departments (administrative subdivisions). In recent years there has been growing interest in composite indicators as an efficient analysis tool and a way of prioritizing policies. These indicators not only enable multi-dimensional phenomena to be simplified but also make it easier to measure, visualize, monitor and compare a country's performance in particular issues. We used data collected from the Colombian Demographic and Health Survey (DHS) for 32 departments and the capital city, Bogotá, in 2005 and 2010. The variables included in the index provide a measure of three dimensions related to child health: health status, health determinants and the health system. In order to generate the weight of the variables and take into account the discrete nature of the data, we employed a principal component analysis (PCA) using polychoric correlation. From this method, five principal components were selected. The index was estimated using a weighted average of the components retained. A hierarchical cluster analysis was also carried out. We observed that the departments ranking in the lowest positions are located on the Colombian periphery. They are departments with low per capita incomes and they present critical social indicators. The results suggest that the regional disparities in child health may be associated with differences in parental characteristics, household conditions and economic development levels, which makes clear the importance of context in the study of child health in Colombia.

JEL classification: I14, J13
Keywords**:** early childhood health, composite indicators, principal component analysis, polychoric correlation, Colombia

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1. Introduction

In recent years there has been a growing interest in measuring and quantifying children's well-being and its main determining factors through the construction of child well-being indicators (Ben-Arieh 2000,2008a, 2008b). Several international studies (mainly on developed countries) confirm this interest. It is worth highlighting the research of the UNICEF Innocenti Research Centre (2007, 2010) for industrialized countries, the studies by Bradshaw et al. (2007) and Bradshaw and Richardson (2009) for European countries, the annual reports from the Kids Count Data Book for the United States by the Annie E. Casey Foundation (Foundation 2010) and, recently, the research on countries located on the Pacific Rim by Lau and Bradshaw (2010). All of these studies build composite indices that seek to capture multiple dimensions that affect children's well-being, from material well-being, health and education to the perspectives children have of their lives and living conditions. In this research we focus on one of the dimensions of child well-being: health in the first years of life.

It is widely accepted that the first years of life are critical to children's development. The vast majority of aspects related to child health are determined in the antenatal, delivery and perinatal period (Rigby and Köhler 2002). Child health starts from conception, with antenatal care followed by delivery conditions. After birth, child health is determined among other things by adequate nutrition, a healthy environment and the possibility of access to health services. Child health is a basic indicator of child well-being and is closely related to poverty and the ability to cover costs for health related services (Spencer 2000). Through the analysis of child health it is possible to identify deficit situations concerning access to and provision of key health facilities. These deficits imply great challenges for public policy and dealing with them highlights the priority that childhood well-being represents in the social and economic agendas of nations.

Interest in monitoring children's well-being started in 1940 with the publication of the UNICEF report on the State of the World's Children. But it was not until the social indicators movement in the 1960s that the field of child well-being indicators began to develop. Since then the children's indicators movement has attracted more and more interest in both policy agendas and the academic community. Thus the emergence and development of this movement is the result of both regulatory factors and the contributions of conceptual theories and methodologies in recent years (Ben-Arieh 2008a).

The UN Convention on the Rights of the Child (CRC) adopted in 1989 offered a regulatory framework through its four core principles (non-discrimination, the best interests of the child, the right to life, survival and development, and respect for the views of the child), which put children on

the global agenda. Moreover, its ratification by 193 countries by 2009 has made it clear that children's well-being today is important in its own right (Bradshaw et al. 2007).

Colombia is no exception to this situation. The priority given to childhood issues in the country is reflected in the regulatory development of the recognition of children's rights and their materialization in better living conditions. The regulatory interest is clearly wide-ranging; examples include the ratification of the CRC in 1991 and the Childhood and Adolescence Code - Act 1098 in 2006 and Act 1295 in 2009 - whose target is children under six years old and pregnant women from lower socioeconomic levels. The guidelines of Colombian public policy in favour of childhood are also reflected in the National Plan on Children and Adolescence 2009-2019. Nevertheless, it is important to monitor how far this interest actually brings about real improvements in well-being for children.

As recently stated by UNICEF (2009), it has become increasingly evident that the deprivation of children's rights to survival and development is particularly concentrated in certain continents, regions and countries. Within nations there are also remarkable disparities in the implementation of children's rights based on circumstances such as geographic location.

Colombia is a heterogeneous country both in its geography and in the level of socioeconomic development among departments. Convergence among Colombian departments[1] and the care allocated to early childhood are two of the priorities of the Colombian government's strategy included in the National Plan of Development 2010-2014. The country has shown significant progress in child health, e.g. in the last five years the under-five mortality rate has fallen from 24 to 19 deaths per 1000 live births, births attended by a doctor have increased by 5 percentage points and immunization coverage rates have reached 84%. However, there are still large differences between departments as well as between urban and rural areas. These differences are reflected in the nutrition indicators for the north coast area, for instance, where the malnutrition rate is four times the national average (Profamilia 2005).

The aim of this paper is to examine how early childhood health varies across Colombian departments. We constructed a composite index of child health using a multivariate statistical approach. Composite indicators have proven to be an efficient tool for analysing and formulating public policies, as well as for bench-marking country performances (Saltelli 2007). They are useful tools for simplifying complex or multidimensional phenomena and making it easier to measure,

[1] Colombia is divided into 32 departments and one capital district (Bogotá), which is treated as a department. Departments are subdivided into municipalities.

visualize, monitor and compare trends in several distinct indicators over time and/or across geographic regions (Michalos et al. 2006). However, they may send misleading policy messages if they are not constructed correctly or if they are misinterpreted (OECD 2008).

Some of the most significant limitations in the construction of composite indicators are related to criteria selection and the number of variables included, the well-being dimension that a variable represents, the weighting and aggregation of the variables and the use of different data sources (Hagerty and Land 2007; Moore 1997). Similarly, the aim and interpretation of the index are also issues of discussion (Moore et al. 2003).

Nevertheless, despite the above limitations, composite indicators are a significant tool for public policy because they enable us to evaluate how far the policy interest expressed in legislation has materialized, in this case for example, in better living conditions for children. They do not necessarily provide an assessment of the results achieved, but they can reflect gaps and deficiencies and make it easier to understand complex situations such as child health.

In order to construct a composite index of child health we used three multivariate statistical methods to generate the weights of the variables. Adopting a statistical approach is another way of selecting and aggregating variables without a priori assumptions in the weighting scheme (Lockwood 2004; Njong and Ningaye 2008). Given the discrete nature of the data, we employed three techniques of dimensionality reduction of the data matrix: principal component analysis (PCA) using binary variables, PCA using polychoric correlations and metric multidimensional scaling (MDS). The results of these techniques of dimensionality reduction of the data indicated that the method which explains a greater percentage of variance with a lower number of components is polychoric PCA. In addition, based on the selected components, a hierarchical cluster analysis was carried out in order to group the departments together according to their health performance rather than their geographic proximity.

We analysed data from the Colombian Demographic and Health Survey carried out in 2005 and 2010. Our Early Childhood Health Index (ECHI) focused on answering the following questions: How child health varies across Colombian departments (administrative subdivisions) and urban-rural areas? Has changed the performance of departments in child health in the last five years? How does departments are clustered according to their child health?

The analysis by department and type of place of residence beyond the national average not only enables us to analyse territorial disparities in key areas for child development, but also leads to

differential strategies in order to reduce place-based inequalities (Coulton and Fischer 2010; Coulton et al. 2009).

The paper is organized as follows. In the next section, methods to construct the index are presented. In Section 3 we describe the data and variables included in the index. An analysis of the results is outlined in Section 4. Finally, the conclusions are summarized in Section 5.

2. Methods

The main purpose of this study is to build a composite index of child health by means of a multivariate statistical approach. One of the most widely used multivariate techniques in composite indexing is principal components analysis. The PCA was originally conceived by Pearson (1901) and further developed by Hotelling (1933). PCA is a multivariate statistical technique of dimensionality reduction, which enables a set of k original correlated variables $X = \{X_1, X_2, \ldots, X_k\}$ to be transformed into a new set of uncorrelated variables called principal components $PC = \{PC_1, PC_2, ..., PC_k\}$. Each component is independent and is a linear weighted combination of the original variables. The first principal component explains the largest proportion of the total variance; the second is orthogonal to the first, with maximal remaining variance, and so on.

The classical PCA assumes that the variables are multivariate normal distributed and therefore work best on continuous data. A solution as to how to incorporate discrete data into PCA was proposed by Filmer and Pritchett (2001). They suggest breaking down the categorical variables into a set of dummy variables. However, the use of dummy variables in PCA introduces spurious correlations, loses all the ordinal information, biases toward the covariance structure and lowers the proportion of explained variance (Kolenikov and Angeles 2009).

Kolenikov and Angeles (2009, 2004) recently described a technique to incorporate categorical variables into PCA using polychoric correlations. They conclude that with this method the proportion of explained variance estimated is more accurate than with other methods. Therefore, if the proportion of explained variance is important to the analysis, polychoric PCA should be used.

The polychoric correlations concept refers to the correlation between two observed variables x and y with r and s ordinal categories respectively. Polychoric correlation coefficients are

estimated by the maximum likelihood method. The objective is to maximize the probabilities that categories s and r are given jointly, weighted by the number of observations (Olsson 1979).
Suppose that x and y are the result of two latent variables, X and Y, which are bivariate normally distributed. Further, x and y are obtained by categorizing these underlying variables according to a set of thresholds $a_i, i = 0,\ldots,s$ and $b_j, j = 0,\ldots,r$ respectively, where $a_0 = b_0 = -\infty$ and $a_s = b_r = +\infty$. If we have a cross-table of x by y, with observed frequencies n_{ij}, then the probability π_{ij} that an observation falls in cell (i, j) is given by

$$\pi_{ij} = \Phi_2(a_i, b_j; \rho) - \Phi_2(a_{i-1}, b_j; \rho) - \Phi_2(a_i, b_{j-1}; \rho) + \Phi_2(a_{i-1}, b_{j-1}; \rho) \tag{1}$$

where Φ_2 is the bivariate normal distribution function with correlation ρ

$$\Phi_2(a_i, b_j; \rho) = \int_{-\infty}^{a_i}\int_{-\infty}^{b_j} \frac{1}{2\pi\sqrt{1-\rho^2}} \exp\left[-\frac{t^2 - 2\rho tz + z^2}{2(1-\rho^2)}\right] dtdz \tag{2}$$

Therefore, the likelihood can be written as

$$\ln L \equiv \sum_{i=1}^{s}\sum_{j=1}^{r} n_{ij} \ln \pi_{ij} \tag{3}$$

This likelihood function depends on ρ and thresholds a_i and b_j. Maximizing these parameters we obtain the polychoric correlation between x and y. Note that like other correlation coefficients (e.g Pearson), when $x = y$ the polychoric correlation is 1. Having obtained the polychoric correlations among pairwise of variables x and y, the correlation matrix is constructed. The PCA is then performed in the usual way.

In addition, based on the selected components, a hierarchical cluster analysis was carried out in order to group departments together according to a distance measurement. Ward's method was

used as a hierarchical agglomerative linkage method. This method forms clusters by maximizing within-cluster homogeneity and is based on the error sum of squares (Timm 2002).

3. Data

The data used in the analysis are drawn from the Colombian Demographic and Health Survey (DHS) conducted in 2005 and 2010. This survey has been carried out in Colombia by Profamilia every 5 years since 1990. It is a nationally representative survey and covers the urban and rural areas of 6 regions (Caribbean, Eastern, Bogotá, Central, Pacific, and Amazon and Orinoco), 16 sub-regions and 33 departments.

DHS data include 14621 (2005) and 17756 (2010) children aged between 0 and 60 months. We selected a set of variables related to health status, health determinants and health system according to both their relevance to the study and the availability of data. We imputed missing data on relevant variables to maximize the sample size. In particular, we fitted a regression model with the weight at birth as the dependent variable and all the other variables as regressors. Our final sample included 8838 (2005) and 11884 (2010) children who were alive at the time of the interview and for whom we had complete information.

3.1. Variables included in the analysis

To quantify early childhood health in Colombia we built a composite index that encompasses three dimensions of health: health status, health determinants and health system. The variables included are defined in Table 1.

Health status included nutrition and recent illnesses. Nutritional status was measured by two anthropometric indicators - stunting and underweight - measured through the height-for-age and the weight-for-age indices respectively. Stunting (defined as being –2 standard deviations below the median height for age), or growth retardation or chronic malnutrition, is an indicator of long-term exposure to nutritional inadequacy. This is related to poor sanitary conditions and socioeconomic circumstances. Underweight (defined as being –2 standard deviations below the median weight for age) or overall undernutrition is an indicator of unavailability of adequate food. Apart from reflecting the current health status of the child, recent illnesses are indicators of the children's living conditions because they reflect a lack of safe drinking water, sanitation and hygiene. We included three dummy variables for recent illnesses: whether the child had had a fever, cough or diarrhoea in the two weeks preceding the interview.

Health determinants were divided into two categories: health determinants at birth and mother's preventive behaviour. In the first we included the person who attended the delivery of the child (doctor, nurse or midwife), the place of delivery (health institution or other) and the child's weight at birth. As recommended by the World Health Organization (WHO), low birth weight is defined as below 2500 grams and is an important predictor of health. This variable is measured in three categories: weight at birth under 2500 grams, over 2500 grams and not weighed.

The mother's preventive behaviour took into account antenatal care, breastfeeding and child immunization. As an indicator of antenatal care we included the number of antenatal visits during pregnancy. It is estimated that at least four visits during pregnancy improves a range of health outcomes for women and children (WHO 2005). This variable is therefore categorized into no antenatal visits, one to three visits and four or more visits. In this category we also included whether the mother received a tetanus toxoid injection during pregnancy.

Breastfeeding reduces infant mortality and has benefits for child health in both the short term and the long term. The WHO recommends that infants should be exclusively breastfed for the first six months with continued breastfeeding for up to two years or longer. This variable is measured by duration in months and has three categories: never breastfed, up to two years and more than two years.

The scope of immunization services and the quality of preventive care provided by health services to children under age 5 are reflected in the coverage of specific vaccines, such as the third dose of DPT. In order to quantify immunization status we included whether the child had received the third dose of DPT and polio and measles vaccine.

Finally, as an indicator of *health system* we took into account whether the child has a health card or not.

3.2. Descriptives

All the descriptive and statistical analyses presented here were corrected by the Stata command ‘svy’, which takes into account the survey design.

The sample proportions by region are shown in Table 2 (results by department are presented in the appendix). The selected categories for each variable correspond to what they should be in order to enjoy good health during childhood. The data show some remarkable facts. Overall, child health in

Colombia was better in 2010 compared to 2005. However, at regional level, the Amazon and Orinoco region did not follow this trend. With the exception of breastfeeding, immunization and health system coverage, all the indicators for this region decreased in 2010. However, it should be noted that this year, unlike 2005, the survey included the rural population of the region in the sample. This could explain the differences with the rest of the country.

Nevertheless, we observe large differences within regions and between departments in both years. For 2010, for instance, the proportion of deliveries attended by a doctor in San Andrés (Atlantic region) was 99%, while in Chocó (Pacific region) it was 67%. Looking within the Pacific region, we observe that in the Valle del Cauca this figure was 93%.

The number of antenatal visits is the variable with the greatest contrast among departments in 2010. While 96% of mothers attended 4 or more check-ups during pregnancy in Quindio, in Chocó it was only 52%. In 2005, the greatest differences between departments are reflected in the place where the birth was attended.

It is worth mentioning the case of Chocó. This department exhibits lower rates in almost all health indicators in both years, but the percentage of mothers who breastfed their children up to 2 years is the highest (98% and 97% respectively), which may be associated with economic restraints in acquiring mother's milk supplements.

4. Results

4.1. Estimation of the Early Childhood Health Index (ECHI) and department rankings

We constructed a composite indicator of early childhood health. This enables departments to be ranked and differences in child health across Colombian regions to be analysed. The indicator is centred on zero, therefore more positive scores indicate departments that have better child health conditions, while those with more negative scores have a worse performance. The indicator enables the health dimensions in which a department presents deficits with respect to the rest of the country to be identified. We expect it to be a useful tool for designing public programmes and allocating resources in favour of children.

We estimated the composite indicator by means of PCA using polychoric correlations. Other methods (PCA using binary variables and multidimensional scaling) not presented here were used to compute the indicator. However, the method that reported the greatest proportion of explained

variance was the polychoric PCA, and therefore the analysis of the results is carried out based on that method.

One widely used criterion for selecting the number of retained principal components is that proposed by Kaiser (1960), which suggests retaining components with eigenvalues greater than 1.0. Based on this criterion we identified five components. These components explain 70% and 68% of the total variance in 2005 and 2010 respectively. It is important to bear in mind that the results of the polychoric PCA were quite similar in both years, which enables us to make comparisons.

The eigenvalues, the variables represented by each component and the rotated matrix of polychoric correlations are presented in Tables 3, 4 and 5. In order to determine whether a variable contributes to a component, we selected the variables with the greatest correlation as long as this correlation is greater than 0.5 and the variable is not linked to another component.

The first component is related to the determinants of health at birth. This component includes the person who attended the delivery, the place of the delivery and the weight at birth. Variables that reflect child health status, such as stunting and recent illnesses, are grouped in the second and third components respectively. In the last two components the dimensions of health concerning health coverage and preventive behaviour of the mother are represented. The fourth component encompasses antenatal care, tetanus injection, child immunization and health card. Finally, breastfeeding is represented in the fifth component. The components are interpreted positively, i.e. the higher the score, the better the child's health.

Two child health indices were estimated. The first index was calculated giving equal weights to each component, and the second was based on a weighted average of the retained components. In the second case, the weights were calculated dividing each eigenvalue into the sum of the eigenvalues retained. Nevertheless, when we used equal weights as the method to estimate the index, the departments' positions did not change significantly. In fact the positions of the departments at the top and bottom of the ranking remained practically the same with both methods. Only a few shifts in the central positions were observed. In this paper we only show the results of the weighted indicator.

The ECHI ranking of Colombian departments in 2010 is reported in Table 6. The departments are ordered by region and the results are presented by urban and rural area. The results indicate that Vaupés, Amazonas, Chocó, Vichada and Guainía are ranked in the lowest positions, while Bogotá,

Quindío, Huila, Risaralda and Valle are at the top of the ranking. This order remains roughly the same for urban and rural areas.

The ranking by components is presented in Table 7. The departments best/worst ranked for each component are: Atlántico/Vaupés (health at birth), San Andrés/Vaupés (nutrition), Boyacá/Amazonas (recent illnesses), Huila/Guainía (health system and preventive behaviour) and Huila/Putumayo (breastfeeding).

The analysis of the ECHI by components shows heterogeneity in the health performance of the departments. There is no department at the top of the indicator which at the same time is at the top in all five components. Bogotá, for instance, which is in first position in the global indicator, is ranked 15 out of 33 for nutrition. Quindío and Huila in the second and third place are ranked 11 and 12 respectively for recent illnesses. In the case of the lowest ranking departments, we note that Vaupés performs very well on breastfeeding but is in the lowest positions in the other health dimensions. However, as mentioned above as regards Chocó, in conditions of poverty an increase in breastfeeding may mean that it is not possible to supplement the child's diet with other foods.

In order to analyse the departments' shift in position from year to year, Figure 1 shows the departments according to the number of positions they moved up or down in 2010 compared to 2005. For comparison purposes the departments from the Amazon and Orinoco region are excluded from the analysis because in 2005 the DHS only included urban data for these departments.

A department's position on the zero line means that it remains in the same position in 2010 as in 2005, while a position above the line means that it has risen in the ranking, i.e. in relative terms this department performed better in child health in 2010.

The figure shows that the Pacific region has not advanced in early child health. There is no department in this region that improved its relative position in 2010. In contrast, 6 of the 7 departments in the Central region rose in the ranking. We observe heterogeneity within the other regions; while some departments improved, others remained in the same place or were worse-off in 2010.

At department level, those that moved up more than five positions were Cesar, Boyacá, Huila and Tolima. The case of Huila should be highlighted as it shifted from being in the lower-middle range of the indicator to being close to the top in third position. The departments that dropped the most

positions were San Andrés and Santander, which shifted from being in the top positions to being in the upper-middle and lower-middle parts of the indicator, and Sucre, which fell 10 positions and was placed at the bottom of the index.

In general there are two clear messages in the results of ranking departments. Firstly, child health performance is heterogeneous. And secondly, the gap between departments has not closed, i.e. the departments that provided better/worse health for their children in 2005 continue to do so in 2010.

4.2. Cluster analysis

From the retained components, a hierarchical cluster analysis was carried out. The clusters by component and the dendogram are presented in Figures 2 and 3. Likewise, the departments by cluster are depicted in Map 1. The cluster analyses enable us to have a different classification of departments, taking into account the characteristics of child health rather than geographical location.

The results indicate that clusters 3 and 4 are formed by the departments that perform best in all components. They are departments located in the centre of the country. These clusters group those departments that are in the top 5 of the indicator. Clusters 1 and 2 show a heterogeneous performance in child health. These clusters are performing better in health at birth, nutrition and preventive care, while they have disadvantages in recent illnesses and breastfeeding. Ten of the eleven departments that form these clusters are located in the north of the country.

The departments of clusters 5 and 6 are located in the peripheral region and show a poor performance on the determinants of health at birth. The departments of cluster 5 are weak in nutrition. Cluster 6 holds a relatively low position in all components. To this latter group belong the five departments in the lowest part of the ECHI.

4.3. External validity of the ECHI

One way to validate an indicator is to explore the relationship between components and index scores and variables that are not included in the index. If the correlation between the indicator and the components and these variables used for validation is good and consistent with the theory, it is considered that the indicator is appropriate (Booysen 2002). To explore this relationship we used the socioeconomic status of the household. It is widely accepted that health inequalities can be

explained by the level of wealth (Marmot et al. 2008). As a validator we used a proxy measure of socioeconomic status (SES) based on ownership of consumer durable goods and housing quality. We constructed the SES index using polychoric PCA. We fitted a linear regression between ECHI and SES. The estimated slope is 0.485 and is statistically significant at 1% level, so there is a positive and significant relation between child health and socioeconomic status (see Table 8).

5. Conclusion

In this paper we present a description of early childhood health in Colombia by department and place of residence (urban-rural) through the construction of a composite indicator of child health. We have used data from the Colombian Demographic Health Surveys of 2005 and 2010, taking into account several dimensions of children's health from before birth through to their first five years of life. We compute our Early Child Health Index using three statistical multivariate methods that enable us to include categorical variables: PCA using binary variables, PCA using polychoric correlations and metric multidimensional scaling. The results show that the method that estimates a greater proportion of the explained variance is the polychoric PCA. From this method we selected five principal components that are related to the determinants of health at birth, health status and the health system.

The analysis of the ECHI indicates that the performance of departments varies by component. A department can be performing very well in one component but at the same time may be in the lowest position in another health dimension. With regard to place of residence, we find that rural areas have more child health needs compared to urban areas. Also, according to the evidence of economic and social indicators in Colombia, we find a positive association between performance in child health and the socioeconomic conditions of the departments. However, this issue is not dealt with in depth in this paper. The departments with the best child health conditions are those where the economic activity of the country is concentrated and poverty rates are lower. The departments ranking at the bottom have the highest levels of poverty.

A hierarchical cluster analysis was also carried out. We observed that departments that perform well in all the components of early childhood health are located in the centre of the country. They are the departments with the greatest economic competitiveness. In contrast, those departments that are unable to provide good child health are located in the Pacific, Atlantic, and Amazon and Orinoco regions, which together are known as the peripheral region. This region is characterized by having per capita GDP levels well below the national average, little State presence, a hostile environment and a large proportion of the country's ethnic minorities (Meisel 2007; Galvis and

Meisel 2010). For these reasons, in this region it should be a priority to design policies aimed mainly at the health care of mother and child at birth, as well as the development of programmes that aim to improve departmental equity in access to key goods and facilities for child well-being.

Finally, it should be noted that although child health is a considerable dimension of child well-being, clearly it is not the only aspect. Therefore the analysis should be complemented by identifying other dimensions that provide a more complete vision of child well-being. It is also desirable to identify and incorporate other variables into the analysis of child health, as well as other methods of missing data imputation and other validation techniques. That being said, the methodological approach employed here - through the construction of a weighted index - makes it easier to understand the relative status of child health in Colombia. We hope that this study helps to draw policy makers' attention to this vulnerable population and that it may be used as a criterion for the allocation of public funds.

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ANNEX

Table 1 Definition of variables

Variable	Description	Values
Health status		
stunting	Child's height for age is below -2SD	0=No 1=Yes
undwt	Child's weight for age is below -2SD	0=No 1=Yes
diarr	Child had diarrhoea in last two weeks	0=No 1=Yes
fever	Child had fever in last two weeks	0=No 1=Yes
cough	Child had cough in last two weeks	0=No 1=Yes
Health determinants		
-Health at birth		
doctor	Doctor attended the delivery	0=No 1=Yes
nurse_midw	Nurse/midwife attended the delivery	0=No 1=Yes
deliplace	Place of the delivery	0=Home and others 1=Health institution
birth_wt	Weight at birth	0=Less than 2500g 1=More than 2500g 2=Not weighed
-Preventive behaviour		
breast	Months of breastfeeding	0=Never breastfed 1=Up to 2 years 2=More than 2 years
antcare	Number of antenatal visits	0= No antenatal visits 1= 1-3 visits 2=4 or more
tetanus	Mother received tetanus toxoid injection	0=No 1=Yes
immu	Child received Polio3, DPT3 and Measles vaccines	0=No 1=Yes
Health system		
hcard	Child has health card	0=No 1=Yes

Table 2 Sample proportions of variables included in Early Childhood Health Index by region (N_{2005}=8838 N_{2010}=11884)

	Atlantic		Eastern		Central		Pacific		Amazon and Orinoco		Bogotá		Colombia Total	
	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010	2005	2010
Health status														
No stunting	0.89	0.90	0.91	0.93	0.92	0.93	0.90	0.92	0.93	0.91	0.88	0.90	0.90	0.92
No underweight	0.91	0.94	0.91	0.96	0.94	0.97	0.94	0.96	0.94	0.94	0.95	0.96	0.94	0.96
No fever	0.72	0.67	0.74	0.76	0.72	0.71	0.75	0.76	0.72	0.69	0.78	0.80	0.74	0.73
No diarrhoea	0.82	0.84	0.84	0.86	0.84	0.85	0.85	0.87	0.84	0.84	0.86	0.91	0.84	0.86
No cough	0.53	0.43	0.62	0.63	0.58	0.58	0.62	0.57	0.62	0.60	0.60	0.65	0.58	0.57
Health determinants														
Doctor attended delivery	0.88	0.94	0.92	0.95	0.88	0.95	0.83	0.88	0.95	0.85	0.98	0.98	0.89	0.94
Delivery in health institution	0.90	0.96	0.95	0.96	0.91	0.96	0.87	0.89	0.96	0.87	0.99	0.99	0.92	0.95
Weight at birth >2500g	0.85	0.89	0.87	0.90	0.88	0.89	0.84	0.85	0.91	0.87	0.84	0.87	0.86	0.88
Breastfeeding up to 2 years	0.91	0.91	0.85	0.87	0.89	0.91	0.91	0.91	0.88	0.89	0.88	0.88	0.89	0.90
Received tetanus toxoid injection	0.93	0.94	0.91	0.90	0.86	0.87	0.91	0.90	0.89	0.84	0.90	0.92	0.90	0.90
4 or more antenatal visits	0.80	0.90	0.85	0.88	0.85	0.91	0.85	0.87	0.85	0.80	0.91	0.94	0.85	0.90
Received DPT3, Polio3 and measles	0.78	0.81	0.86	0.85	0.81	0.84	0.81	0.85	0.81	0.85	0.82	0.84	0.81	0.84
Health system														
Has health card	0.76	0.88	0.78	0.81	0.85	0.87	0.83	0.90	0.77	0.82	0.83	0.75	0.81	0.84

Table 3 Eigenvalues of Early Childhood Health Index

Component	Eigenvalues	Proportion explained	Cum. explained
	2005		
1	3.4836	0.2724	0.2724
2	1.8804	0.1389	0.4113
3	1.8215	0.1226	0.5339
4	1.4332	0.0950	0.6289
5	1.2520	0.0762	**0.7050**
	2010		
1	3.1996	0.2504	0.2504
2	2.0184	0.1431	0.3936
3	1.7558	0.1165	0.5101
4	1.4746	0.0939	0.6040
5	1.0406	0.0738	**0.6778**

Table 4 Variables and dimensions by principal component

Component	Dimension	Variables
PC1	Health at birth	Doctor attended delivery Nurse/midwife attended delivery Place of delivery Weight at birth
PC2	Health status	Stunting Underweight
PC3	Health status	Recent illnesses
PC4	Health determinants and Health system	Antenatal care Tetanus injection Immunization Health card
PC5	Health determinants	Breastfeeding

Table 5 Polychoric correlation matrix 2010

Variable		PC 1	PC 2	PC 3	PC 4	PC 5
antcare						
	No antenatal visits	-0.5122	-0.4563	-0.0571	**-0.7123**	-0.3292
	1-3 visits	-0.2742	-0.3125	-0.0485	-0.4488	-0.1578
	4 or more	0.5093	0.4911	0.0628	**0.7508**	0.2678
tetanus						
	No	-0.1983	-0.3330	-0.0142	**-0.6349**	-0.5465
	Yes	0.1983	0.3329	0.0142	**0.6349**	0.5464
doctor						
	No	**-0.8517**	-0.3247	-0.0303	-0.3652	-0.0802
	Yes	**0.8516**	0.3246	0.0303	0.3652	0.0802
nurse_midw						
	No	**-0.8252**	-0.2436	0.0041	-0.1418	-0.2140
	Yes	**0.8251**	0.2435	-0.0041	0.1418	0.2140
deliplace						
	Home and others	**-0.9274**	-0.3250	-0.0287	-0.3828	-0.1122
	Health institution	**0.9273**	0.3250	0.0287	0.3828	0.1122
birth_wt						
	Less than 2500g	**0.7661**	-0.3670	0.0356	-0.1553	-0.1680
	More than 2500g	0.2745	0.3902	-0.0073	0.3196	0.1632
	Not weighed	**-0.7508**	-0.2314	-0.0316	-0.3585	-0.0981
immu						
	No	-0.0472	0.4697	0.1734	**-0.6871**	-0.6080
	Yes	0.0472	-0.4697	-0.1734	**0.6871**	0.6080
breast						
	Never breastfed	0.1023	-0.0350	-0.0244	0.0865	**-0.9673**
	Up to 2 years	0.0345	0.1236	-0.0334	-0.0695	-0.4297
	More than 2 years	-0.0663	-0.1332	0.0485	0.0539	**0.9788**
stunting						
	No	0.1783	**0.8401**	0.0446	0.0043	-0.0211
	Yes	-0.1783	**-0.8401**	-0.0446	-0.0043	0.0211
undwt						
	No	0.1137	**0.7427**	0.1107	0.0341	-0.0728
	Yes	-0.1137	**-0.7426**	-0.1107	-0.0341	0.0728
diarr						
	No	0.0987	0.2383	**0.6549**	-0.0953	0.0546
	Yes	-0.0987	-0.2383	**-0.6550**	0.0953	-0.0546
fever						
	No	0.0363	-0.0231	**0.8990**	0.0346	0.0071
	Yes	-0.0363	0.0231	**-0.8990**	-0.0346	-0.0071
cough						
	No	-0.0322	-0.0025	**0.8569**	0.0115	0.1427
	Yes	0.0322	0.0025	**-0.8570**	-0.0115	-0.1427
hcard						
	No	-0.1270	0.0649	-0.0183	**-0.5056**	0.2445
	Yes	0.1270	-0.0648	0.0183	**0.5058**	-0.2445

Table 6 ECHI ranking of departments by urban-rural area 2010

Department	Urban	Rural	Total
Atlantic Region			
Atlántico	9	11	7
Bolívar	20	18	18
Cesar	17	8	15
Córdoba	21	20	23
Guajira	18	27	27
Magdalena	24	16	20
Sucre	27	23	22
San Andrés	13	6	10
Eastern Region			
Boyacá	12	7	9
Cundinamarca	11	3	8
Meta	15	13	14
Norte de Santander	7	17	11
Santander	26	14	19
Central Region			
Antioquia	10	15	13
Caldas	16	12	16
Caquetá	14	25	24
Huila	1	5	**3**
Quindío	3	4	**2**
Risaralda	4	2	**4**
Tolima	6	19	12
Pacific Region			
Cauca	22	26	28
Chocó	28	31	*31*
Nariño	23	22	25
Valle	8	1	**5**
Amazon and Orinoco Region			
Arauca	5	10	6
Casanare	25	21	21
Putumayo	29	24	26
Amazonas	31	30	*32*
Guainía	30	29	*29*
Guaviare	19	9	17
Vaupés	33	32	*33*
Vichada	32	28	*30*
Bogotá	2		**1**

Table 7 Ranking by principal components 2010

Department	PC1	PC2	PC3	PC4	PC5
Atlantic Region					
Atlántico	**1**	**5**	28	12	13
Bolívar	16	**4**	29	16	24
Cesar	13	11	26	**3**	20
Córdoba	21	16	22	28	32
Guajira	26	29	32	26	23
Magdalena	15	23	31	9	16
Sucre	20	18	30	13	28
San Andrés	11	**1**	17	19	21
Eastern Region					
Boyacá	14	25	**1**	6	**5**
Cundinamarca	8	17	**3**	17	10
Meta	17	9	14	20	9
Norte de Santander	12	10	21	11	**2**
Santander	22	19	6	14	12
Central Region					
Antioquia	9	13	19	23	27
Caldas	10	21	24	7	25
Caquetá	24	12	25	27	18
Huila	6	7	11	**1**	**1**
Quindío	**2**	8	12	**2**	15
Risaralda	**5**	6	7	**4**	17
Tolima	19	**3**	8	10	6
Pacific Region					
Cauca	28	27	15	21	26
Chocó	31	28	27	30	31
Nariño	25	24	**5**	18	30
Valle	7	**2**	9	**5**	14
Orinoco and Amazon Region					
Arauca	**4**	14	10	15	7
Casanare	23	20	13	22	11
Putumayo	27	26	18	24	33
Amazonas	32	32	33	29	29
Guainía	29	31	16	33	8
Guaviare	18	22	4	25	19
Vaupés	33	33	20	32	**3**
Vichada	30	30	23	31	22
Bogotá	**3**	15	**2**	8	**4**

Table 8 Coefficient for Early Childhood Health Index (ECHI) on Socioeconomic Status (SES)

	Coefficient	Standard errors
SES	0.4850	(0.008)***
Constant	4.05E-09	(0.008)
Number of obs.	11884	
R-squared	0.2353	

***Significance at 1.

Fig. 1 Number of positions that a department shifted up or down in the ranking in 2010 with respect to 2005

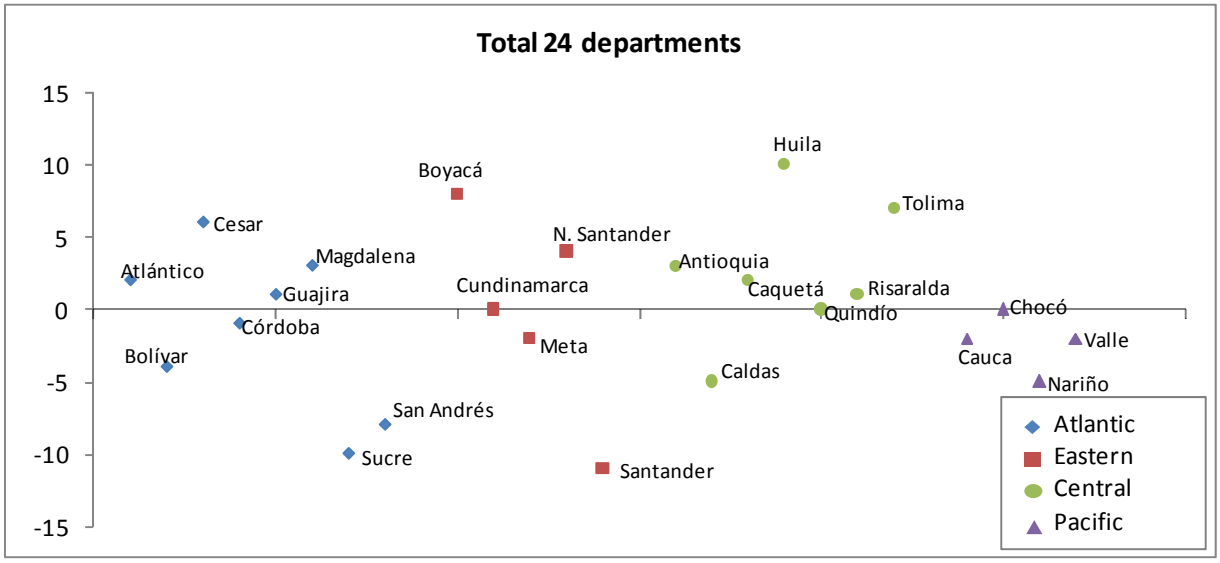


Fig. 2 Dendogram for Early Childhood Health Index 2010

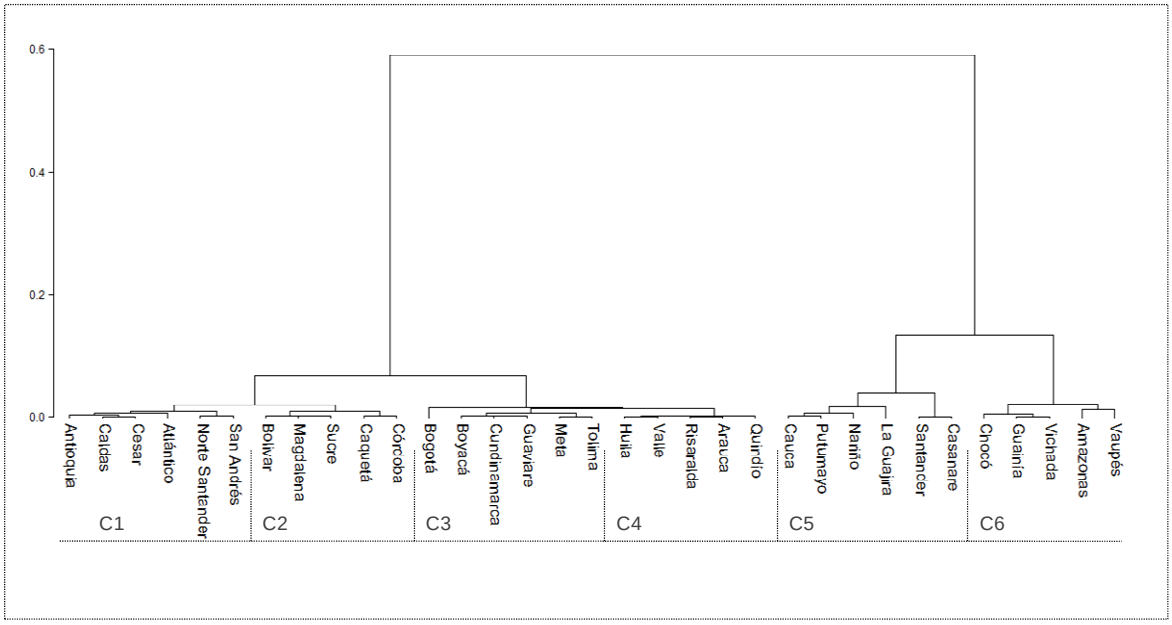
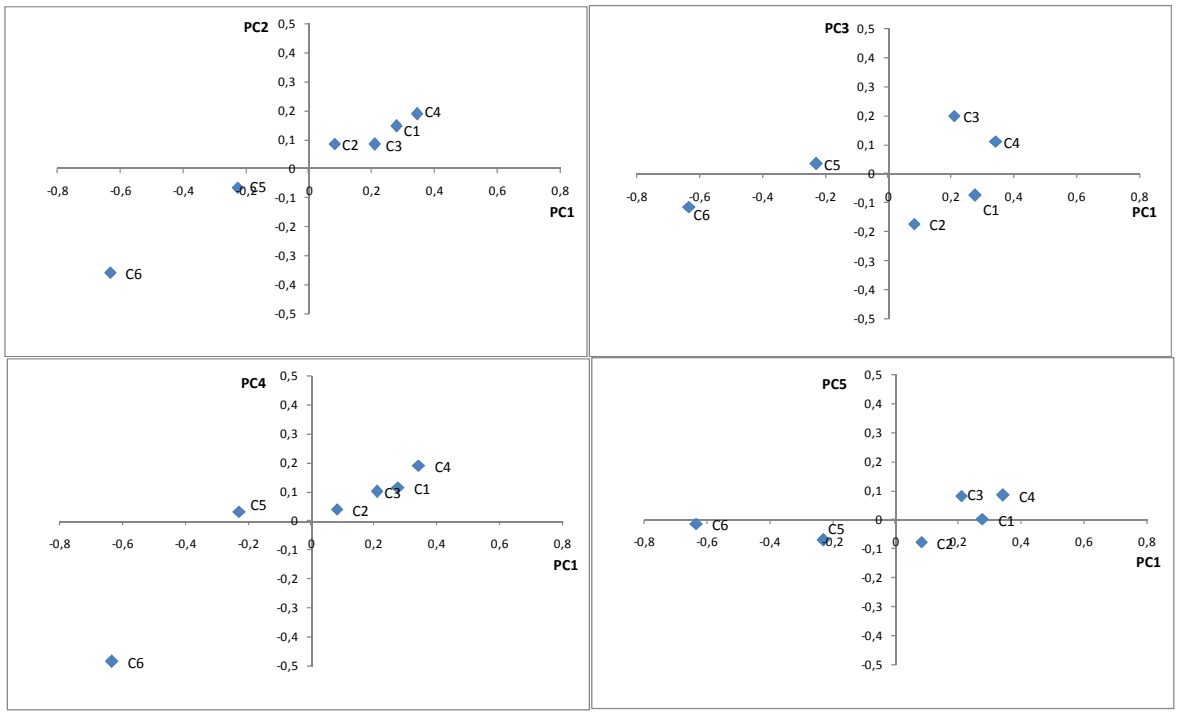
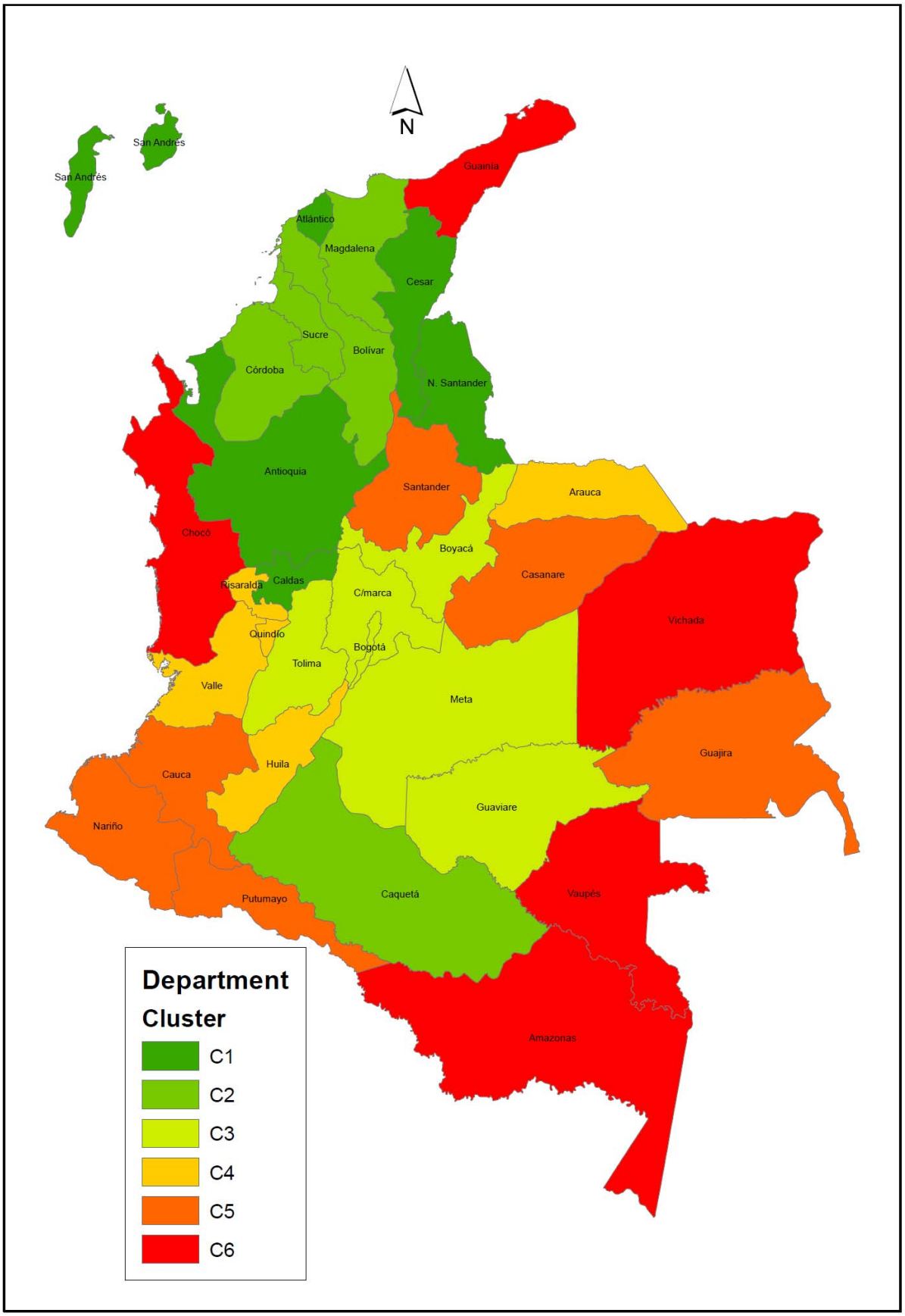


Fig. 3 Principal components by cluster 2010



Map. 1 Colombian Early Childhood Health Index 2010
Departments grouped by cluster



Appendix

Sample proportions of variables included in Child Health Index (N_{2005}=8838 N_{2010}=11884)

		Health at birth			Nutrition		Recent Illnesses			Breastfeeding	Antenatal Care		Vaccination	Health coverage
Departments		Doctor attended delivery	Delivery place: Health Inst.	Weight at birth >2500g	No Stunting	No Under weight	No fever	No diarrhoea	No cough	Breastfeeding up to 2 years	Received tetanus toxoid injection	4 or more antenatal visits	Received DPT3, Polio3 and measles	Has health card
Atlantic Region														
Atlántico	2005	0.96	0.88	0.88	0.91	0.93	0.77	0.85	0.58	0.89	0.92	0.88	0.82	0.77
	2010	0.99	0.99	0.89	0.92	0.97	0.64	0.88	0.41	0.92	0.94	0.94	0.82	0.92
Bolivar	2005	0.92	0.81	0.85	0.88	0.92	0.73	0.78	0.53	0.94	0.96	0.86	0.83	0.78
	2010	0.95	0.97	0.91	0.93	0.96	0.66	0.84	0.39	0.94	0.97	0.91	0.76	0.86
Cesar	2005	0.78	0.75	0.85	0.91	0.91	0.65	0.82	0.36	0.90	0.95	0.79	0.77	0.79
	2010	0.94	0.96	0.91	0.92	0.94	0.72	0.81	0.47	0.92	0.96	0.90	0.85	0.88
Córdoba	2005	0.82	0.70	0.75	0.87	0.88	0.76	0.87	0.61	0.92	0.89	0.72	0.73	0.79
	2010	0.93	0.94	0.86	0.90	0.95	0.70	0.85	0.51	0.90	0.91	0.86	0.78	0.88
La Guajira	2005	0.78	0.78	0.74	0.82	0.88	0.69	0.79	0.44	0.93	0.84	0.65	0.67	0.62
	2010	0.82	0.86	0.81	0.83	0.89	0.62	0.82	0.43	0.92	0.87	0.81	0.84	0.83
Magdalena	2005	0.81	0.73	0.8	0.88	0.93	0.68	0.79	0.46	0.92	0.92	0.73	0.75	0.67
	2010	0.92	0.95	0.90	0.87	0.91	0.69	0.79	0.39	0.91	0.94	0.89	0.83	0.84
Sucre	2005	0.93	0.78	0.87	0.92	0.93	0.66	0.81	0.6	0.89	0.97	0.84	0.80	0.82
	2010	0.93	0.95	0.87	0.90	0.93	0.64	0.81	0.45	0.87	0.93	0.89	0.81	0.88
San Andrés	2005	0.99	0.95	0.92	0.99	0.96	0.84	0.94	0.81	0.88	0.94	0.95	0.79	0.74
	2010	0.99	1.00	0.92	0.96	0.97	0.71	0.87	0.54	0.89	0.90	0.91	0.79	0.77
Eastern Region														
Boyacá	2005	0.88	0.86	0.78	0.82	0.90	0.78	0.88	0.76	0.87	0.89	0.75	0.83	0.67
	2010	0.97	0.97	0.91	0.86	0.94	0.81	0.88	0.68	0.89	0.91	0.91	0.85	0.80
Cundinamarca	2005	0.95	0.92	0.86	0.92	0.97	0.77	0.85	0.69	0.83	0.89	0.87	0.87	0.73
	2010	0.95	0.97	0.88	0.92	0.97	0.79	0.87	0.67	0.86	0.89	0.88	0.84	0.87
Meta	2005	0.91	0.80	0.88	0.93	0.95	0.81	0.87	0.71	0.88	0.92	0.81	0.83	0.75
	2010	0.94	0.96	0.91	0.96	0.98	0.77	0.84	0.56	0.87	0.87	0.88	0.83	0.90
Norte de Santander	2005	0.88	0.73	0.88	0.91	0.98	0.65	0.8	0.48	0.88	0.96	0.87	0.87	0.83
	2010	0.93	0.94	0.91	0.95	0.95	0.69	0.84	0.55	0.88	0.95	0.86	0.85	0.80

Santander	2005	0.95	0.92	0.87	0.94	0.96	0.73	0.83	0.51	0.83	0.91	0.86	0.85	0.89
	2010	0.93	0.97	0.90	0.94	0.95	0.76	0.86	0.62	0.84	0.87	0.89	0.87	0.72
Central Region														
Antioquia	2005	0.90	0.80	0.87	0.91	0.95	0.70	0.83	0.51	0.89	0.82	0.87	0.81	0.90
	2010	0.96	0.97	0.88	0.94	0.97	0.68	0.85	0.57	0.92	0.81	0.91	0.85	0.87
Caldas	2005	0.91	0.83	0.88	0.94	0.95	0.71	0.85	0.50	0.92	0.86	0.90	0.88	0.80
	2010	0.95	0.98	0.90	0.89	0.95	0.68	0.82	0.54	0.89	0.87	0.90	0.86	0.86
Caquetá	2005	0.62	0.61	0.79	0.91	0.92	0.72	0.82	0.62	0.90	0.89	0.68	0.72	0.74
	2010	0.82	0.85	0.90	0.95	0.95	0.72	0.82	0.47	0.91	0.92	0.81	0.81	0.90
Huila	2005	0.87	0.74	0.86	0.91	0.94	0.72	0.9	0.61	0.88	0.94	0.82	0.84	0.81
	2010	0.95	0.97	0.92	0.93	0.96	0.75	0.86	0.61	0.89	0.97	0.93	0.86	0.87
Quindío	2005	0.96	0.96	0.87	0.93	0.96	0.8	0.88	0.71	0.85	0.86	0.94	0.88	0.74
	2010	0.98	0.98	0.92	0.93	0.95	0.76	0.88	0.57	0.90	0.92	0.96	0.86	0.92
Risaralda	2005	0.97	0.93	0.93	0.94	0.96	0.74	0.81	0.66	0.89	0.91	0.90	0.88	0.87
	2010	0.97	0.99	0.93	0.94	0.96	0.74	0.87	0.65	0.90	0.95	0.92	0.84	0.81
Tolima	2005	0.82	0.78	0.82	0.92	0.90	0.74	0.9	0.78	0.85	0.91	0.81	0.76	0.76
	2010	0.91	0.93	0.92	0.94	0.98	0.75	0.84	0.63	0.85	0.92	0.92	0.82	0.85
Pacific Region														
Cauca	2005	0.64	0.67	0.69	0.87	0.91	0.69	0.80	0.57	0.91	0.86	0.75	0.70	0.73
	2010	0.76	0.77	0.83	0.85	0.95	0.77	0.82	0.55	0.92	0.88	0.81	0.84	0.93
Chocó	2005	0.56	0.51	0.78	0.95	0.96	0.66	0.74	0.45	0.98	0.92	0.73	0.68	0.75
	2010	0.67	0.72	0.83	0.90	0.94	0.68	0.79	0.47	0.97	0.86	0.67	0.80	0.81
Nariño	2005	0.82	0.66	0.80	0.82	0.93	0.74	0.83	0.6	0.9	0.92	0.81	0.87	0.83
	2010	0.88	0.89	0.82	0.91	0.96	0.79	0.87	0.59	0.94	0.83	0.86	0.87	0.92
Valle	2005	0.93	0.91	0.88	0.94	0.95	0.78	0.90	0.66	0.90	0.92	0.91	0.84	0.88
	2010	0.95	0.97	0.87	0.96	0.98	0.75	0.90	0.58	0.89	0.93	0.94	0.85	0.89
Amazon and Orinoco Region														
Arauca	2005	0.95	0.93	0.90	0.92	0.91	0.71	0.87	0.62	0.88	0.92	0.84	0.83	0.80
	2010	0.97	0.97	0.93	0.90	0.96	0.69	0.92	0.64	0.88	0.86	0.89	0.85	0.87
Casanare	2005	0.99	1.00	0.91	0.97	0.95	0.75	0.85	0.63	0.86	0.83	0.93	0.77	0.72
	2010	0.91	0.95	0.91	0.95	0.95	0.74	0.90	0.56	0.87	0.85	0.84	0.89	0.69
Putumayo	2005	0.95	0.91	0.92	0.91	0.97	0.76	0.88	0.69	0.90	0.90	0.85	0.81	0.73
	2010	0.86	0.86	0.90	0.93	0.93	0.66	0.81	0.64	0.93	0.83	0.82	0.85	0.87
Amazonas	2005	0.92	0.93	0.85	0.89	0.92	0.6	0.72	0.49	0.90	0.9	0.78	0.82	0.82

	2010	0.63	0.66	0.72	0.83	0.94	0.59	0.71	0.47	0.90	0.86	0.68	0.80	0.89
Guainía	2005	0.92	0.93	0.89	0.93	0.95	0.63	0.73	0.39	0.85	0.84	0.74	0.80	0.84
	2010	0.74	0.77	0.80	0.84	0.92	0.70	0.82	0.63	0.81	0.69	0.66	0.78	0.89
Guaviare	2005	0.87	0.86	0.89	0.95	0.94	0.60	0.70	0.47	0.87	0.94	0.85	0.85	0.78
	2010	0.93	0.95	0.83	0.93	0.95	0.74	0.84	0.70	0.87	0.83	0.90	0.81	0.87
Vaupés	2005	0.83	0.81	0.85	0.87	0.88	0.72	0.78	0.66	0.84	0.89	0.59	0.83	0.91
	2010	0.68	0.71	0.72	0.76	0.95	0.64	0.84	0.59	0.78	0.85	0.52	0.80	0.89
Vichada	2005	0.91	0.92	0.90	0.90	0.93	0.82	0.86	0.68	0.87	0.89	0.82	0.78	0.85
	2010	0.73	0.75	0.78	0.91	0.93	0.73	0.73	0.59	0.88	0.78	0.59	0.81	0.84
Bogotá	2005	0.98	0.86	0.82	0.88	0.95	0.78	0.86	0.6	0.88	0.90	0.91	0.82	0.83
	2010	0.98	0.99	0.87	0.90	0.96	0.80	0.91	0.65	0.88	0.92	0.94	0.84	0.75
Colombia	2005	0.89	0.82	0.84	0.9	0.94	0.74	0.84	0.58	0.89	0.81	0.84	0.81	0.81
	2010	0.94	0.95	0.88	0.92	0.96	0.73	0.86	0.57	0.90	0.90	0.90	0.84	0.84

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