*Apuntes* 88, 77-113
ISSN: 0252-1865
eISSN: 2223-1757
doi: 10.21678/apuntes.88.1293


Article received on November 22, 2019
Final version approved for publication on November 20, 2020

# Socioeconomic and proximate determinants of mortality in children under five years of age in Peru (2015–2018)

RENE PAZ PAREDES MAMANI
*Universidad Nacional del Altiplano*
rpparedes@unap.edu.pe

CRISTOBAL YAPUCHURA SAICO
*Universidad Nacional del Altiplano*
cyapuchura@hotmail.com

ROBERTO ARPI MAYTA
*Universidad Nacional del Altiplano*
rarpi@unap.edu.pe

ALFREDO PELAYO CALATAYUD MENDOZA
*Universidad Nacional del Altiplano*
alfredopelayo@yahoo.com

*Abstract.* The objective of this study is to find the socioeconomic and proximate determinants of mortality in children under five years of age in Peru. To this end, the study focuses on the theoretical approach of Mosley and Chen (1984) and employs the econometric methodology of the Cox semi-parametric and proportional hazards model and the Kaplan and Meier non-parametric model. With regard to socioeconomic determinants, the results show that the years of maternal education, household economic status, and the mother's health coverage significantly reduce the risk of death for children under the age of five. Likewise, the years of maternal education has a significant interaction effect with the household socioeconomic level and access to health service coverage, which influence child survival. As for the proximate determinants, maternal age, birth intervals, birth order, and health facilities all predict the risk of death for children under five years of age.

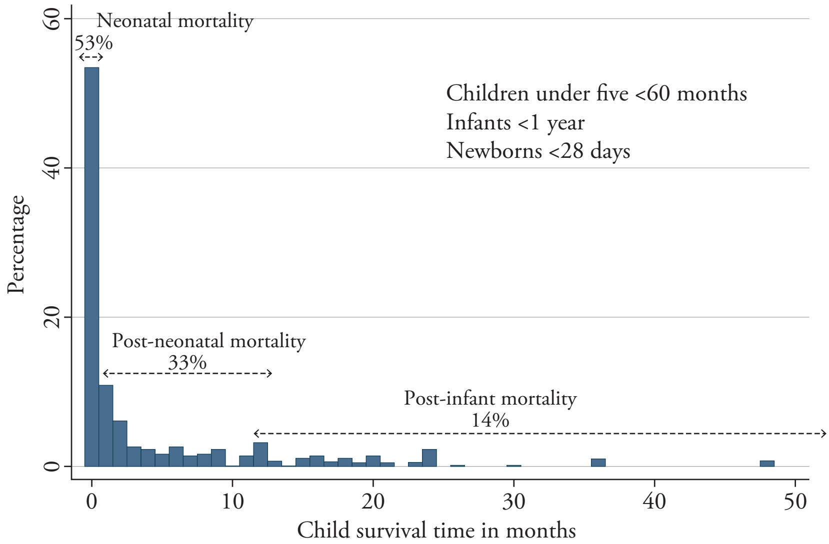
*Keywords*: mortality, survival, Kaplan-Meier, Cox proportional hazards

## 1. Introduction

In recent decades, Peru has undergone profound socioeconomic changes that have influenced the epidemiological, demographic, and nutritional characteristics of the population, including infant mortality (Huynen, Vollebregt, Martens, & Benavides, 2005; Tam, Huicho, Huayanay-Espinoza, & Restrepo-Méndez, 2016).

The mortality rate among children under the age of 5 (known as the child mortality rate) is considered a demographic indicator that reflects the population wellbeing of a country (Nyinawajambo, 2018; Yu et al., 2018); therefore, one of the targets of Sustainable Development Goal (SDG) 3 is to, "by 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1,000 live births and under-5 mortality to at least as low as 25 per 1000 live births." (World Health Organization, 2018). The child mortality rate reflects the probability that a child will die between birth and reaching the age of five, and is expressed in 1 per 1,000. In 1992, 78 out of every 1,000 children in Peru died before their fifth birthday, a figure that dropped by 76% to 19 per 1,000 children in 2018 (Appendix 1). However, inequalities associated with geographical area, maternal education, socioeconomic level, and other socioeconomic characteristics persist (Appendix 2). Moreover, a high percentage of deaths occur in the first few months of life. Indeed, in the period 2015–2018 (Figure 1) and in 2018 itself, 53% of deaths among children under the age of five corresponded to newborns (Appendix 1).

Figure 1
Distribution of deaths among children under five years of age




Source: compiled by authors based on the Encuesta Demográfica y Salud Familiar (ENDES–2015, 2016, 2017, and 2018)

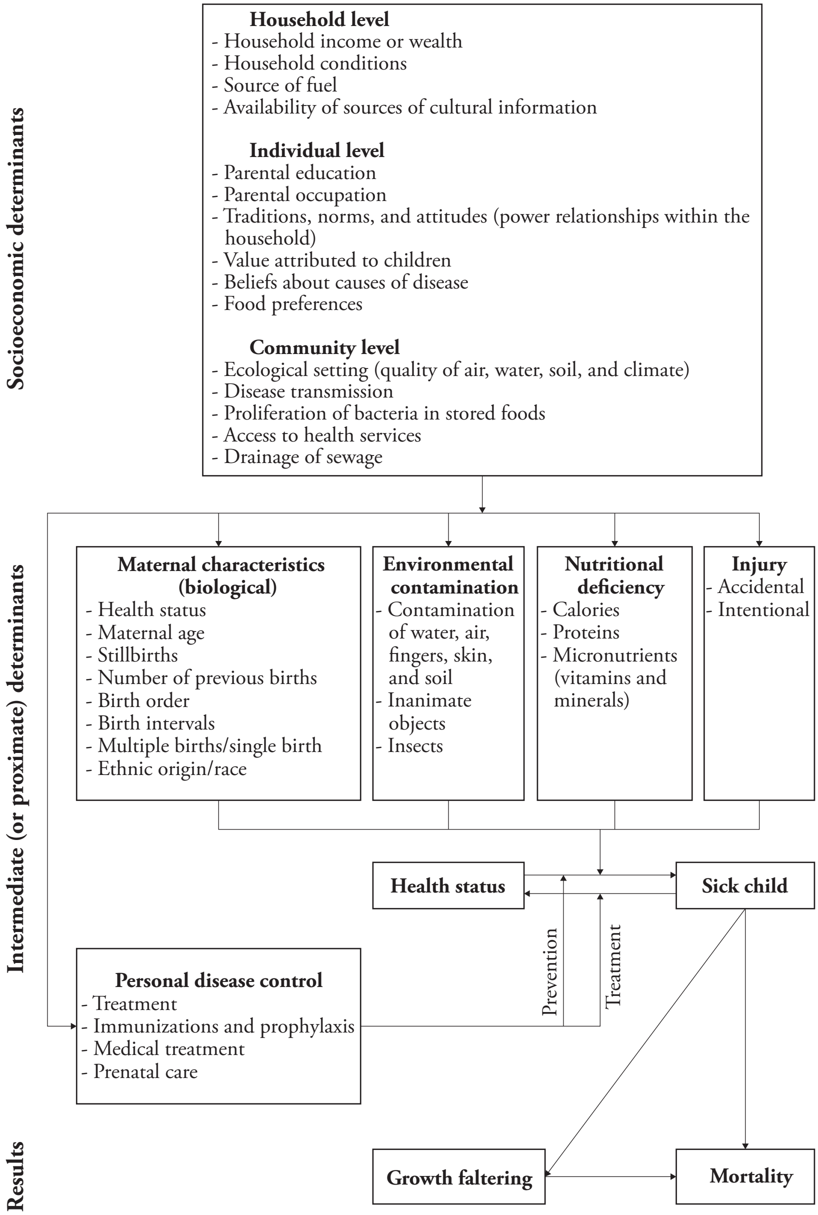
Mosley and Chen (1984) propose an analytical model for the study of infant survival in developing countries. Their approach incorporates socioeconomic and biological variables to explain child survival, and is based on the premise that, to make an impact, all socioeconomic determinants of infant mortality necessarily operate through a common set of biological mechanisms, or proximate determinants. For these authors, the most important consideration is identifying the proximate determinants, or intermediate variables, that directly influence this type of mortality. Their model stresses the social and medical roots of child mortality based on the standard epidemiological approach, which begins by investigating a biological problem in the human host and then seeks its social determinants to develop rational control measures.

Mosley and Chen (1984) group together five categories of intermediate (or proximate) determinants: i) maternal factors: mother's age, parity, birth interval; ii) environmental contamination: air, food/water/fingers, skin/soil/inanimate objects, insect vectors; iii) nutrient deficiency, calories; protein, micronutrients (vitamins and minerals); iv) injury: accidental, intentional; and v) personal illness control: personal preventive measures, medical treatment (Figure 2).

In turn, socioeconomic determinants (independent variables) act through proximate variables to influence the level of growth faltering and mortality (Mosley & Chen, 1984). These authors place these determinants into three broad categories: (i) individual-level variables: the productivity of household members (fathers, mothers, children); traditions, norms, and attitudes linked to power relationships within the household; ii) household-level variables: income/wealth, occupation, and housing quality; and iii) community-level variables: ecological setting, political economy, health system.

Among the socioeconomic determinants, maternal education as a measure of human capital (Bicego & Ties Boerma, 1993; Breierova & Duflo, 2004; Strauss & Thomas, 1995) is the most important predictor of child mortality and health (Caldwell & Caldwell, 1983), more so even than paternal education, health service availability, and socioeconomic status (Frost, Forste, & Haas, 2005). More specifically, maternal education contributes to improved infant health outcomes through socioeconomic status, health knowledge, attitudes to modern healthcare, female autonomy, and reproductive behavior (Desai & Alva, 1998; Frost et al., 2005). Other findings reveal that the higher the mother's level of education (Kaberuka, Mugarura, Tindyebwa, & Bishop, 2017) and the household's socioeconomic status, the lower the rate of infant mortality (Biradar, Patel, & Prasad, 2019; Iram & Butt, 2008; Kanté et al., 2016; Yu et al., 2018).

Figure 2
Conceptual diagram of socioeconomic and proximate determinants of child mortality




Source: adapted from Mosley & Chen (1984)

As far as maternal age is concerned, some studies point to a relationship between mortality rate and the extremes of fertility: that children born to mothers younger than 15 and older than 35 face a higher risk of death (Finlay, Özaltin, & Canning, 2011; Kato et al., 2017; Ribeiro, Pimenta, Lopes, Dalmas, & Giroto, 2014). The causes of this phenomenon among the former group are associated with the lack of a stable partner, lack of paid work, late access to antenatal care, and fewer antenatal visits. In the second group, the risk is related to greater incidence of hypertension during pregnancy, operative delivery, and congenital anomalies.

As to the relationship between the under-five mortality rate and birth order, various studies observe that first- and last-born children face a greater probability of death; that is, the association is U-shaped. Other analyses report a greater probability of dying in the first months only; that is, an L-shape (Biradar et al., 2019; Kaberuka et al., 2017; Mondal, Hossain, & Ali, 2017) and others still, a J-shape, indicating a greater probability of death in the final months of pregancy (Mishra, Ram, Singh, & Yadav, 2017).

In Peru, considerable efforts have been made to construct databases to measure child survival; however, there is still a lack of national-level data with which to explore the survival status and immediate determinants of mortality among children under five years of age. In this regard, the main aim of the present article is to identify the survival status and the socioeconomic and proximate determinants of children under five using microdata from Peru's Demographic and Family Health Survey (Encuesta Demográfica y Salud Familiar, ENDES).

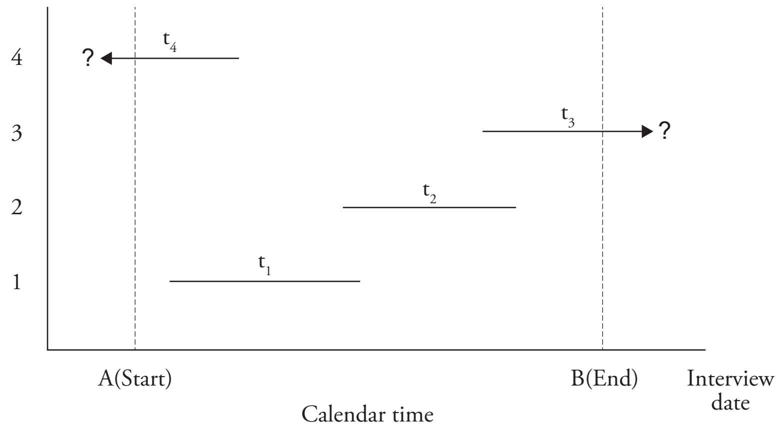
## 2. Materials and methods

The methodology for estimating a child's probability of survival can be divided into two broad groups: non-linear probability models (logit and probit), and duration models (parametric and non-parametric). The first group only estimates the probability of an event occurring in a single period of time; thus, these models analyze whether a child died or survived within a given period (Dammert, 2003). Therefore, this group of models is not appropriate when the research question involves the time lapse until an event occurs, or estimation of the average survival period beyond a pre-determined interval (the five-year survival rate). Unlike the first group, duration models can be used to estimate not only a child's probability of death, but also time to death (Beltrán & Grippa, 2006; Dammert, 2003; Kaplan & Meier, 1958).

Duration models (or survival models) seek to explain the time determinants of a given situation before a change to another state. In the case of children under five, these models estimate the probability of survival for each period of less than five years based on socioeconomic and proximate determinants of mortality. A common characteristic of these models is that they contain censored data; that is, when the data pertaining to an individual's life span is incomplete within the period of study (Kaplan & Meier, 1958). The right censoring at B (Figure 3) occurs when all that is known is that an individual is still alive at a given moment, while the left censoring at A (Figure 3) takes place when it is only known that an individual has experienced the "event of interest" (that is, death) before the start of the study (Dammert, 2003; Dietz, Gail, Krickelberg, Samet, & Tsiatis, 2003).

In the sample of children used here, some will have both been born and died during the five-year period of study, which means that the data is complete for the event to be analyzed t1 and t2 (Figure 3). For children who were born in and survived through the period of study (d=0), the interval is incomplete and provides only partial data about survival time, but is used to estimate the probabilities of survival; these observations are known as right-censored data (t3). On the other hand, for children who were born before the period of study, no data are available during the first months of life, and so these observations are considered left-censored (t4).

Figure 3
Censured data




| | | |
|---|---|---|
| A | : | start of study period |
| B | : | end of study period |
| $t_1$ and $t_2$ | : | completion of transition |
| $t_3$ | : | right-censored period |
| $t_4$ | : | left-censored period |

Source: Dammert (2003)

**Kaplan-Meier non-parametric estimation**

For the Kaplan-Meier model (Córdova et al., 2018; Kaplan & Meier, 1958), we denote as $h_j$ the number of deaths of duration $t_j$, where j = 1, . .. , K months, and as $m_j$ the number of right-censored observations between $t_j$ and $t_{j+1}$. We define $n_j$ as the number of complete or non-truncated events before a duration $t_j$:

$$n_j = \sum_{i>j}^{k} (m_i + h_i) \qquad (1)$$

The hazard rate $b(t_j)$ is the probability of completion of an event in duration tj, which leads to the event reaching duration tj, and can be defined as:

$$\hat{b}(t_j) = h_j / n_j \qquad (2)$$

That is, it is the number of completed events in $t_j$ divided by the number of non-completed events in $t_j$. As a result, there is a conditional probability of survival in the i-th interval, given that survival occurred in the previous period,

as $p_i = [1 - \hat{b}_i]$. On this basis, we obtain the Kaplan-Meier estimator:

$$\hat{S}(t_j) = \prod_{i=1}^{j} \frac{(n_i - h_i)}{n_i} = \prod_{i=1}^{j} (1 - \hat{b}_i) \qquad (3)$$

**Parametric estimation**

An essential element in the analysis of survival is the risk function (Dietz et al., 2003). If T denotes the time to death, the hazard function, or instantaneous failure rate, is defined by:

$$\mathrm{b}(t) = \underbrace{\lim}_{\Delta t \to \infty} \frac{[t \leq T < t + \Delta t \mid T \geq t]}{\Delta t} = \frac{f(t)}{S(t)} \qquad (4)$$

This occurs if T is a non-negative random continuous variable that denotes time to death. The distribution of T ≥ 0 can be characterized by its probability density function *f(t)* and accumulated distribution function *F(t)*; thus, the survival function, that is, the probability that a child can survive beyond time *t*, is as follows:

$$S(t) = 1 - F(t) = \mathrm{P}(T > t) \qquad (5)$$

Where $F(t) = \mathrm{P}(T \leq t)$ is the failure function; thus, the survival function S(t) expresses the probability that an event of interest has not yet occurred in period t. Meanwhile, the hazard rate is defined as (Dietz et al., 2003):

$$\mathrm{b}(t) = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{S(t)} = \frac{-d\ln(S(t))}{dt} \quad (6)$$

The risk function provides relevant information on the duration dependence in relation to time: if $\partial b(t)/\partial t > 0$ for any n $t = t*$, the probability of leaving the initial state increases with time. If $\partial b(t)/\partial t < 0$; then the same probability of leaving the initial state holds regardless of time. This type of behavior is known as a memoryless process. If $\partial b(t)/\partial t = 0$ is a memoryless process, then the same probability of leaving the initial state holds regardless of the time spent in that state. There is a one-to-one relationship between a specification for the hazard rate and the survival function. The hazard or accumulated failure function H(t) is defined by:

$$H(\mathrm{t}) = \int_0^t \mathrm{b}(u)du = -\ln(S(t)) \geq 0 \quad (7)$$

Thus, for continuous life functions:

$$S(t) = \mathrm{e}^{[-H(t)]} = \mathrm{e}^{\left[-\int_0^t b(u)du\right]} \quad (8)$$

There are many general forms for the hazard rate; the only restriction is that $b(t)$ not be negative.

**Cox proportional model**

This model is semi-parametric, in that the parametric form is only assumed for the effect of the covariates (X). If $b(t|X)$ is the hazard rate in period t for an individual with a hazard vector X, the basic model based on Cox (1972) is as follows:

Where $b_i(t)$ is the hazard rate in period t of the i-th child; $b_0(t)$ is the random baseline hazard rate in period t and represents the probability of the child dying before any exposure to X (Fotso, Cleland, Mberu, Mutua, & Elungata, 2013); that is, it captures the individual heterogeneity not contained in the explanatory variables ; $\beta = (\beta_1,\ldots, \beta_p)$ is a $e^{\sum_{i=1}^{p}\beta_i X_i}$ vector of parameters and $e_{i=1}$ is an exponential function, which represents the relative hazard or proportionality factor.

Thus, the hazard increases or decreases in proportion to a vector of individual characteristics X. The Cox proportional hazard model is estimated without imposing restrictions on the base risk function; the unknown parameters to be estimated are the parameters $\beta$ and the baseline hazard rate $b_0(t)$.

The measure of the effect of given covariates in the survival time is given by the hazard ratio (HR). If we consider a two-categorical variable, say X=1 and X=0, then the hazard ratio for the two groups is defined as:

$$HR = \frac{b_i(t|X=1)}{b_0(t|X=0)} = e^{\sum_{i=1}^{p} \beta_i X_i} \quad (10)$$

If HR = 1, this implies that the individuals in the two categories face the same risk of experiencing the event, when HR> 1 implies that individuals in the first category (X = 1) face the same risk of experiencing the event, and if HR <1, individuals in the second category (X = 0) are at high risk of experiencing the event. Because $e^{\beta_i X_i}$ is constant in time, the hazard function, for individual i, $b_i(t)$, is parallel to the baseline hazard function $b_0(t)$.

Therefore, the survival function of child *i* is an exponential constant of the base survival function, that is:

$$S_i(t, X, \beta) = [S_0(t)] e^{X_i \beta} \quad (11)$$

For the proportional hazard function, the $\beta$ parameters can be interpreted as time displacements in the hazard function. The result can be interpreted as factors that affect the hazard, in relation to the baseline hazard, or the essential life function, $S_0(t)$.

$$S_0(t) = e^{\left[-\int_0^t b_0(t)dt\right]} = [H_0(t)] \quad (12)$$

Where $H_0(t)$ is the cumulative baseline hazard function.

## Data

To analyze the survival of children under five, we employ the ENDES data presented in Table 1.

Table 1
Sample of children

| Years | Sample of children |
|---|---|
| 2015 | 15,940 |
| 2016 | 14,251 |
| 2017 | 14,072 |
| 2018 | 15,426 |
| Total | 59,689 |

Source: compiled by authors based on ENDES (2015, 2016, 2017, and 2018)

The description of the variables employed in the estimation of the Kaplan-Meier duration and the Cox proportional hazards regression models are shown in Table 2, while the descriptive statistics corresponding to the variables are presented in Appendix 3.

Table 2
Description of variables

| Notation | Name | Type of variable | Values |
|---|---|---|---|
| b7 | Age of child at death (survival time) | Quantitative | 0 to 59 months |
| b5 | Child is alive | Dichotomous | 1: alive; 0: dead |
| b3 | Date of birth in century month code (CMC) | Continuous | 1101,…,1428 |
| v008 | Date of interview in century month code (CMC) | Continuous | 1160,…,1428 |
| v008-b3 | Survival time for live children in months | Continuous | 0,…,59 months |
| v133 | Maternal education in years | Continuous | 0,…,18 years |
| v190 | Household wealth index | Ordered categorical | 1: very poor<br>2: poor<br>3: medium<br>4: wealthy<br>5: very wealthy |
| v025 | Area residence | Dichotomous | 1: urban<br>0: rural |
| v013 | Maternal age in five-year groups | Ordered categorical | 1: (15-19 years)<br>2: (20-24 years)<br>3: (25-29 years)<br>4: (30-34 years)<br>5: (35-39 years)<br>6: (40-44 years)<br>7: (45-49 years) |
| Bord | Birth order | Ordered categorical | 1: first birth<br>2: second birth<br>3: third birth<br>4: fourth and beyond |
| b0 | Multiple birth | Dichotomous | 1: single; 0: multiple |
| v481 | Mother's healthcare coverage (HCC_ Mother) | Dichotomous | 1: yes; 0: no |

| | | | |
|---|---|---|---|
| b11 | Interval since previous birth | Continuous | 0,…,300 months |
| b4 | Child's sex | Dichotomous | 1: male<br>0: female |
| v113 | Source of drinking water | Dichotomous | 1: tap water<br>0: well water |
| v116 | Type of sanitation facilities | Ordered categorical | 1: Flush toilet<br>2: well and unimproved toilet<br>3: no toilet |
| Age_15-19 | Mothers belonging to the group of 15 to 19 year olds | Dichotomous | 1: if in the 15-19 group<br>0: otherwise |
| Age_20-24 | Mothers belonging to the group of 20 to 24 year olds | Dichotomous | 1: if in the 20-24 group<br>0: otherwise |
| SES_Poor | Household of poor socioeconomic status | Dichotomous | 1: if poor<br>0: otherwise |
| ISE_Middle | Household of middle socioeconomic status | Dichotomous | 1: if middle status<br>0: otherwise |
| SES_Wealthy | Household of wealthy socioeconomic status | Dichotomous | 1: if wealthy<br>0: otherwise |
| SES_Very wealthy | Household of very wealthy socioeconomic status | Dichotomous | 1: if very wealthy<br>0: otherwise |
| Sex_female | Child's sex | Dichotomous | 1: if female<br>0: if male |
| b111 | Interval since previous birth in years | Ordered categorical | 1: less than 1 year<br>2: less than 2 years<br>3: more than two years |
| Interval≤2years | Interval since previous birth ≤ 2 years | Dichotomous | If less than 2 years<br>0: otherwise |
| Interval>2years | Interval since previous birth > 2 years | Dichotomous | 1: if more than 2 years<br>0: otherwise |
| Order Birth>3 | Birth order > 3 births | Dichotomous | 1: If more than 3<br>0: otherwise |

| | | | |
|---|---|---|---|
| Water_Well | Source of water is well | Dichotomous | 1: if source is well<br>0: otherwise |
| Area_Rural | Rural geographical area | Dichotomous | 1: If rural<br>0: otherwise |
| Well/ unimproved_ toilet | Households with well or unimproved toilet | Dichotomous | If a well or unimproved toilet<br>0: otherwise |
| No_toilet | Households without sanitation facilities (no toilet) | Dichotomous | 1: if no toilet<br>0: otherwise |
| Sregion | Natural region | Ordered categorical | 1: Metropolitan Lima<br>2: rest of coast<br>3: Andes<br>4: Amazonia |

Source: compiled by authors based on ENDES (2015, 2016, 2017, and 2018)

## 3. Results

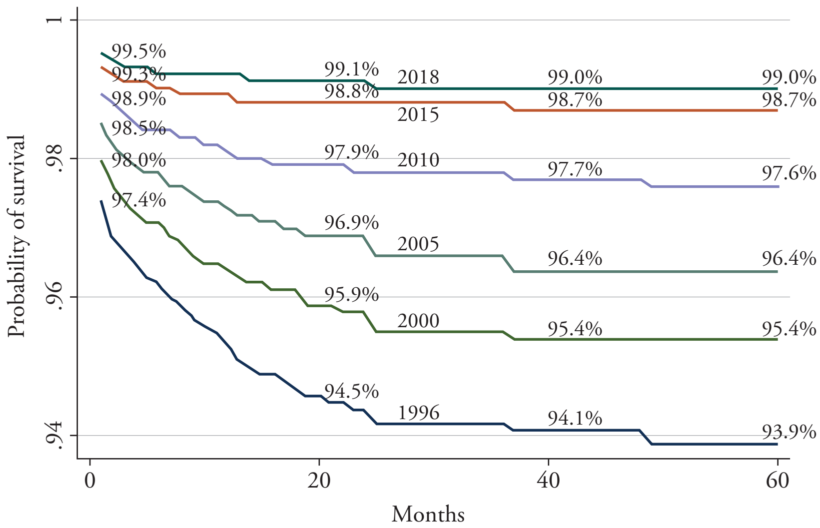
In this section, we present the results of the socioeconomic and proximate determinants of mortality among children under five, according to the methodology employed.

### Results of Kaplan-Meier survival function by years

Between 1996 and 2018, there was an improvement in the survival rate for children under five. Survival during the first month of life rose from 97.4% (1996) to 99.5% (2018), while the rate for the first 59 months increased from 93.9% (1996) to 99% (2018) (Figure 4).

According to the Pan American Health Organization, reduction in the under-five mortality rate is a product of the complex interaction of various factors, and can be seen as a consequence of improved macroeconomic and social conditions such as economic development and better nutrition (Organización Panamericana de la Salud, 2014). Alternatively, it can be read as an effect of state interventions to deliver more efficient public health and enhanced medical technology; this includes control of transmissible diseases, skilled birth attendance, supply of clean water, improved sanitation systems, vaccination campaigns, medically advanced products, and so on. Both views are supported by empirical evidence (Chilupula, 2020; Rosenberg, 2018).

Figure 4
Survival probability curves




Source: compiled by authors based on ENDES (1995, 2000, 2005, 210, 2015, and 2018)

Over the last two decades, a series of programs have contributed to a decline in under-five mortality in Peru. In the 1990s and early 2000s, government and international initiatives aimed at ameliorating food insecurity and promoting family planning in Peru (*Vaso de Leche*, *Comedores Populares*, *Desayunos Escolares*, the National Family Planning and Reproductive Health Program) helped to decrease the fertility rate, but not child malnutrition (Huicho et al., 2016). In 1998, the government launched a health insurance program targeted at mothers and children under the age of five, which became the Comprehensive Health Insurance System (Sistema Integral de Seguro de Salud, SIS) in 2002. The SIS sought to increase healthcare coverage by eliminating user fees for the poor, especially women and children under five years of age.

The Support Program for the Reform of the Health Sector (Programa de Apoyo a la Reforma del Sector de la Salud) was founded in 1999 with a view to improving maternal and infant health and reducing mortality and morbidity among the poor. However, it was only starting in 2002 that the program began to place real emphasis on maternal and infant mortality and morbidity. The program's training component has had a positive effect on the number and proportion of live births, C-sections, oxytocin inductions, and obstetric complications (Rubio, Díaz, & Jaramillo, 2009).

The years since 2005 have witnessed the continual implementation of evidence-based intervention programs that seek to improve reproductive, maternal–neonatal, and infant health through substantial increases in the coverage of antenatal and birth care, as well as the introduction of vaccines. These programs have contributed to further decreases in the child mortality rate (Huicho et al., 2016). Among them, *Juntos* and *Crecer*, both of which emphasize reproductive, maternal, neonatal, and infant health, marked a radical departure from the previous generation of food programs (Huicho et al., 2016).

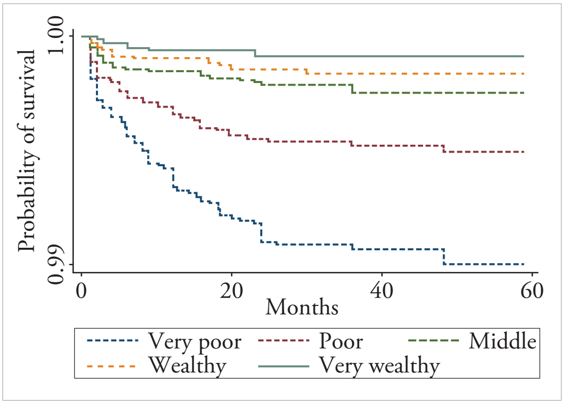
In 2007, the government launched the nationwide *Crecer* strategy to promote coordinated intervention by national, regional, and local entities working on chronic child malnutrition. The purpose of this program was to close the urban–rural gap and its impact on poor families in rural parts of the Andes and Amazonia, and to combine initiatives focusing on health, education, cash transfers, water and sanitation, housing, and agriculture (Huicho et al., 2016). In 2011, the Ministry of Development and Social Inclusion was formed with the aim of improving the quality of life of poor and vulnerable people in a more effective, cohesive manner.

## Results of Kaplan-Meier survival function by selected characteristics

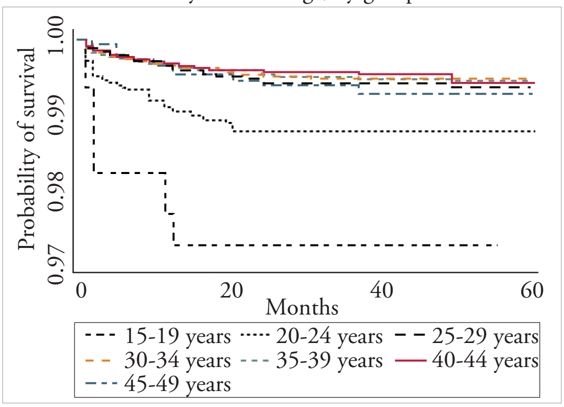
Using the Kaplan-Meier non-parametric method and ENDES data from the period 2015–2018, we calculated the probabilities of survival (or survival function) for children under five years of age (Figure 5): the lower the household socioeconomic status, the lower the probability of survival of under-fives between the period from zero to 59 months, particularly among the poor and very poor (Figure 5, panel 5a).

Figure 5
Results of the Kaplan–Meier non-parametric estimation

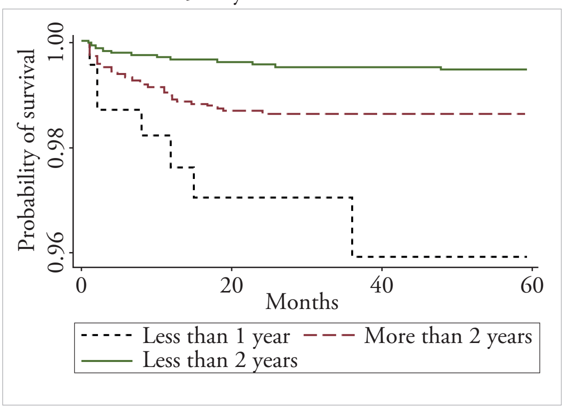
5a. By socioeconomic status



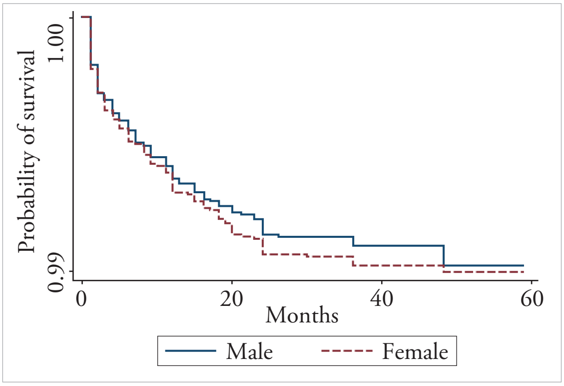

5b. By maternal age, by groups



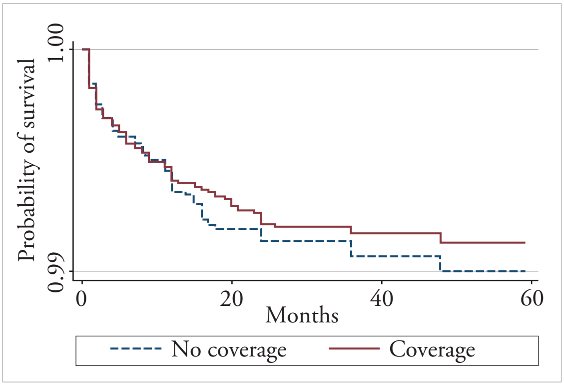

5c. By birth intervals



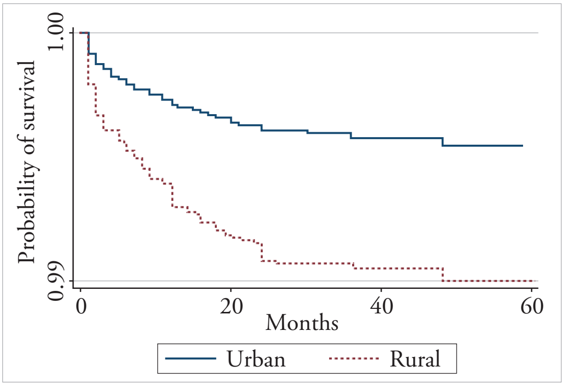
5d. By child's sex



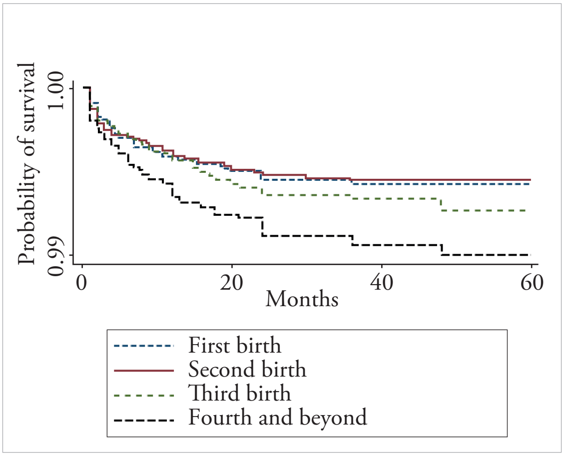

5e. By healthcare coverage



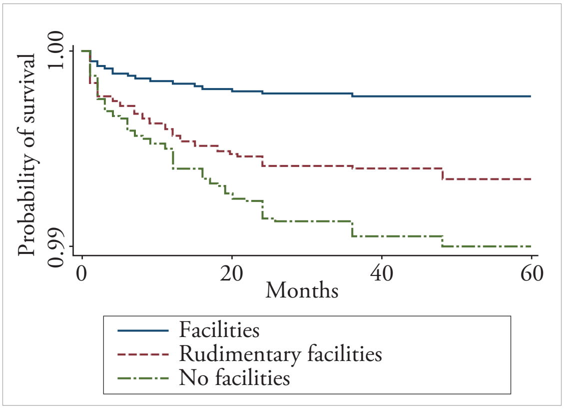

5f. By area of residence



5g. By birth order




5h. By sanitation facilities




Source: compiled by authors based on ENDES (2015, 2016, 2017, and 2018)

When it comes to geographical area, children living in urban environments have a greater probability of survival (Figure 5, panel 5f). As to maternal age, the survival probability curves for children whose mothers are in the 15–19 and 20–24 age brackets are much lower than those for children whose mothers are older than 24. Indeed, among the different groups of mothers over the age of 24, the survival curves are greater, and similar along the entire period (Figure 5, panel 5b). In turn, the results for birth intervals show that the greater the gap between births, the greater the probability of survival for the entire period of zero to 59 months; that is, those born after intervals of less than one year and two years have lower probabilities of survival than those born following an interval of more than two years (Figure 5, panel 5c).

In turn, the survival probability for children whose mothers have health insurance is not markedly different than that of children of mothers who do not, throughout the entire five-year period of study. (Figure 5, panel 5e). Children below the age of five who are born fourth or later have lower probabilities of survival (Figure 5, panel 5g). Finally, children from households with sanitation facilities enjoy greater survival probabilities (Figure 5, panel 5h).

**Estimation of Cox proportional hazard model parameters**

We used the Cox proportional risk model to identify the role of socioeconomic and proximate determinants of mortality among children under five. As far as socioeconomic determinants are concerned, we established that years of maternal education, household socioeconomic status, and the mother's health insurance cover were statistically significant in explaining infant mortality. Among the proximate determinants, variables linked to maternal biological characteristics (such as age, birth order, and birth intervals) as well as type of sanitation facilities proved revealing (Tables 3 and 4).

With regard to socioeconomic status, the results show that the higher the household status, the lower the risk of death for under-fives. For example, the risk is reduced by 32.4% (HR=0.676) for a child from a poor household in comparison with a child from a lower socioeconomic stratum (that is, a very poor household), while in the case of a child from a very wealthy household, the risk is reduced by 81.1% (HR=0.189) (Table 3, Model 1). Similar results were obtained for children of very poor socioeconomic status in Nigeria (Biradar et al., 2019) and Bolivia (Córdova et al., 2018).

As regards years of maternal education, the child's risk of death falls by 5% for each additional year thereof (HR=0.949). Similarly, the children of mothers who have healthcare coverage have a 26.2% lower probability of death (HR=0.738) compared with children whose mothers are not covered (Table 3, model 1). And when the years of maternal education interacts with healthcare coverage, the result obtained is notable (Table 3, Model 2). We find that for each additional year of education among mothers who have healthcare coverage, the risk of death faced by their children falls by 3% (HR=0.969) in comparison with children of uncovered mothers (Table 3, Model 2).

In the case of interaction between the years of maternal education and household socioeconomic status, the results are statistically significant (Table 4, Model 3). They predict that the greater the years of maternal education and the higher the household socioeconomic status, the lower the risk of death for children under five.

As to the interaction between household socioeconomic status and the mother's healthcare coverage (Table 4, Model 4), our results anticipate that the higher the household socioeconomic status of mothers with healthcare coverage, the lower the risk of death for children under five. The interaction between the wealthy and very wealthy socioeconomic strata are particularly revealing. Model 1 without interactions (Table 3) predicts that children of covered mothers will be 26% less likely to die than children whose mothers do not have coverage.

Finally, we estimated the interactive effect of the years of maternal education, the mother's healthcare coverage, and the household socioeconomic status on under-five mortality: among mother's with healthcare coverage, the greater the number of years of education and the higher the household socioeconomic status, the lower the risk of death of children under five.

In the case of type of sanitation facilities, the results are significant at the 1% level of children. Children living in housing without sanitation facilities are twice as likely to die in comparison with children in housing with improved sanitation facilities, across all models (tables 3 and 4).

Table 3
Socioeconomic and proximate determinants of mortality among under-fives

| | Variables | Model 1 | | | Model 2 | |
|---|---|---|---|---|---|---|
| | | HR | Coefficient (HR-1) | p-value | HR | p-value |
| **Socioeconomic determinants** | Years of maternal education | 0.949*** | -0.0521*** | 0.002 | | |
| | Household socioeconomic status (SES) | | | | | |
| | SES_Poor | 0.676** | -0.391** | 0.019 | 0.647*** | 0.008 |
| | SES_Middle | 0.393*** | -0.933*** | 0.000 | 0.363*** | 0.000 |
| | SES_Wealthy | 0.303*** | -1.193*** | 0.000 | 0.268*** | 0.000 |
| | SES_Very wealthy | 0.189*** | -1.665*** | 0.001 | 0.160*** | 0.000 |
| | Area of residence | | | | | |
| | Area_Rural | 0.793 | -0.231 | 0.104 | 0.809 | 0.134 |
| | Mother's healthcare coverage | | | | | |
| | HCC_Mother | 0.738** | -0.303** | 0.045 | | |
| | (years of maternal education)x(HCC_Mother) | | | | 0.969*** | 0.017 |
| **Intermediate (or proximate) determinants** | **Mother and child's biological characteristics** | | | | | |
| | Mother's age | | | | | |
| | Age_15-19 | 3.444*** | 1.236*** | 0.000 | 3.607*** | 0.000 |
| | Age_20-24 | 1.843*** | 0.612*** | 0.000 | 1.859*** | 0.000 |
| | Interval since previous birth | | | | | |
| | Interval≤2years | 0.388** | -0.944** | 0.016 | 0.385*** | 0.015 |
| | Interval>2years | 0.179*** | -1.715*** | 0.000 | 0.178*** | 0.000 |
| | Birth order | | | | | |
| | Order_Birth>3 | 1.306** | 0.267** | 0.043 | | |
| | Child's sex | | | | | |
| | Sex_female | 1.083 | 0.0801 | 0.478 | 1.083 | 0.481 |
| | **Environmental factors** | | | | | |
| | Source of drinking water | | | | | |
| | Water_Well | 0.943 | -0.0586 | 0.644 | 0.949 | 0.681 |
| | Well/unimproved toilet | 1.328* | 0.284* | 0.09 | 1.339* | 0.08 |
| | No_toilet | 1.689*** | 0.524*** | 0.009 | 1.725*** | 0.006 |
| Number of observations | | 58914 | | | 58914 | |
| Wald-Chi²(15) | | 226 | | | 238 | |
| Prob > chi² | | 0.000 | | | 0.000 | |
| Log likelihood | | -3266 | | | -3269 | |

Note. *** p<0.01, ** p<0.05, * p<0.1 (p = probability)
Source: compiled by authors based on ENDES (2015, 2016, 2017, and 2018)

In the case of maternal age, the findings are statistically significant at the 1% level, and the model predicts that children of adolescent mothers (between 15 and 19) are three times more likely to die than those whose mothers are older than 24. This result holds across all models estimated (Tables 3 and 4).

Table 4
Socioeconomic and proximate determinants of mortality among under-fives, with interactions of socioeconomic determinants

| | Variables | Model 3 | | Model 4 | | Model 5 | |
|---|---|---|---|---|---|---|---|
| | | HR | p-value | HR | p-value | HR | p-value |
| **Socioeconomic determinants** | Years of maternal education | | | 0.936*** | 0.000 | | |
| | Mother's healthcare coverage | 0.743* | 0.051 | | | | |
| | (Years of maternal education) x(SES-Poor) | 0.962*** | -0.012 | | | | |
| | (Years of maternal education) x(SES-Middle) | 0.912*** | 0.000 | | | | |
| | (Years of maternal education) x(ISE-Wealthy) | 0.901*** | 0.000 | | | | |
| | (Years of maternal education) x(SES-Very wealthy) | 0.871*** | 0.000 | | | | |
| | (HCC-Mother)x(SES-Poor) | | | 0.878 | 0.361 | | |
| | (HCC-Mother)x(SES-Middle) | | | 0.719 | 0.134 | | |
| | (HealthCC-Mother)x(SES-Wealthy) | | | 0.383*** | 0.01 | | |
| | (HealthCC-Mother)x(SES-Very wealthy) | | | 0.407* | 0.061 | | |
| | (Years of maternal education)x(HCC_Mother)X(SES-Poor) | | | | | 0.983 | 0.257 |
| | (Years of maternal education)x(HCC_Mother)X(SES-Middle) | | | | | 0.956** | 0.026 |
| | (Years of maternal education)x(HCC_Mother)X(SES-Wealthy) | | | | | 0.911*** | 0.004 |
| | (Years of maternal education)x(HCC_Mother)X(SES-Very wealthy) | | | | | 0.911*** | 0.008 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Mother's biological characteristics** | | | | | | | |
| Intermediate (or proximate) determinants | Maternal age | | | | | | |
| | Age_15-19 | 3.520*** | 0.000 | 3.704*** | 0.000 | 4.036*** | 0.000 |
| | Age_20-24 | 1.807*** | 0.000 | 1.923*** | 0.000 | 1.942*** | 0.000 |
| | Interval since previous birth | | | | | | |
| | Interval≤2years | 0.382** | 0.000 | 0.384** | 0.015 | 0.387** | 0.016 |
| | Interval>2years | 0.176*** | 0.000 | 0.176*** | 0.000 | 0.178*** | 0.000 |
| | Birth order | | | | | | |
| | Order_Birth>3 | 1.379** | 0.012 | 1.34** | 0.028 | 1.510*** | 0.001 |
| | **Environmental factors** | | | | | | |
| | Type of sanitation facilities | | | | | | |
| | Well/unimproved toilet | 1.3362* | 0.051 | 1.534*** | 0.004 | 1.761*** | 0.000 |
| | No_toilet | 1.737*** | 0.003 | 1.962*** | 0.000 | 2.327 | 0.000 |
| Number of observations | | 58914 | | 58,914 | | 58914 | |
| Wald -Chi$^2$ | | 225.76 | | 227.12 | | 217.48 | |
| Prob > chi$^2$ | | 0.000 | | 0.000 | | 0.000 | |
| Log likelihood | | -3271.33 | | -3274.1 | | -3282 | |

Note. *** p<0.01, ** p<0.05, * p<0.1.
Source: compiled by authors based on ENDES (2015, 2016, 2017, and 2018)

Children's birth order is another statistically important predictor of mortality among children under five. For all models estimated, the probability of death for children born fourth or later is approximately three times greater in comparison with those born first, second, or third.

In turn, the model forecast that children in housing without improved sanitation facilities are almost twice as likely to die than children whose housing does have these facilities. The result is acceptable at the 1% level of significance in all models (Tables 3 and 4).

## 4. Discussion of results

Maternal education and socioeconomic status are significant predictors of child mortality; these results are consistent with those of Dammert (2003). Maternal education proves significant even when the proximate determinants are included in the estimation. Meanwhile, children from poorer socioeconomic strata face a higher probability of death, as other studies indicate (Biradar et al., 2019; Iram & Butt, 2008; Kanté et al., 2016; Yu et al., 2018). Income level can also have an influence on the child's birth circumstances by way of biological factors such as maternal age or birth interval.

However, once the child is born, the biological characteristics of both the mother and the child are more prevalent (Sullivan, Rutstein, & Bicego, 1994).

Maternal education is well documented by a large number of studies in different countries (Ayele, Zewotir, & Mwambi, 2017; Bicego & Ties Boerma, 1993; Biradar et al., 2019; Breierova & Duflo, 2004; Dammert, 2003; Desai & Alva, 1998; Frost et al., 2005; Iram & Butt, 2008; Kaberuka et al., 2017; Strauss & Thomas, 1995) as the most important predictor of child mortality and health (Caldwell & Caldwell, 1983). Using data for 117 countries around the world, Rosenberg notes that the most potent control variables for explaining infant mortality rates are the mother's level of income and education, followed by quality of governance (2018). Maternal education has interactive effects with socioeconomic status and healthcare coverage when it comes to explaining the risk of mortality among under-fives, in that maternal education is conducive to the acquisition of capabilities that influence child survival. Previous studies find that better educated mothers are more likely to take their children to modern health facilities to receive treatment. Research has also shown that mothers educated to a higher level are more autonomous in their decision-making about the health of their children (Caldwell & Caldwell, 1983; Desai & Alva, 1998; Kiross, Chojenta, Barker, Tiruye, & Loxton, 2019; Vikram, Desai, & Vanneman, 2010).

As well as greater knowledge and skills, more-educated women have a more privileged position in society in comparison with their less educated counterparts, which enables them to access better medical attention from healthcare providers; that is, they are more capable of navigating the bureaucratic healthcare systems. What is more, the language and communication style of women with higher educational and socioeconomic levels can facilitate respectful communication with healthcare providers (Vikram et al., 2010). Better-educated women also pertain to a higher socioeconomic strata and therefore have greater decision-making autonomy (Caldwell & Caldwell, 1983). Finally, years of maternal education interacts not only with the socioeconomic determinants of child mortality, but also with the variables related to proximate determinants, including environmental and biological ones (Kiross et al., 2019; Vikram et al., 2010).

In respect to birth intervals, children under five born after a two-year gap are 82.1% (HR=0.179) less likely to die in comparison with those born after intervals of less than one year ($p<0.001$). Other studies reveal that these longer intervals contribute to a reduction in the risks of mortality (Biradar et al., 2019; Córdova et al., 2018; Curtis, Diamond, & McDonald, 1993), while shorter gaps of less than two years increase the risk of death (Biradar et al., 2019; Tariku, 2019), which may also be associated with maternal education (Vikram et al., 2010).

As to contamination factors, we detected that children who live in households without sanitation facilities, or those with only a water well or unimproved toilet, are more at risk of death than children from households with flush toilets. This is because precarious sanitation contributes to acute respiratory conditions and diarrhea, which are the biggest killers of under-fives. According to the seminal contribution of Mosley and Chen (1984), contamination of water, air, food, fingers, soil and inanimate objects as well as insect vectors are the primary forms of transmitting respiratory diseases. Similar results were obtained by Bellido, Barcellos, Barbosa, and Bastos (2010) for Brazil; that is, there is a direct relationship between inadequate sanitation (half-pipe drains, unimproved cesspools, and garbage disposal in wasteland or public areas) and under-five mortality due to waterborne diseases. Thus, sanitation appears to have a more pronounced effect on mortality than water (Abou-ali, 2003).

Finally, Alsan and Goldin (2019) obtained solid evidence that effective pure water and sewerage systems initiated by far-sighted public servants and engineers reduced deaths of under-fives by one third between 1890 and 1920 in Massachusetts, USA. Over the same period in that state, the under-five mortality rate was 6.7 deaths for every 1,000 children during the warmer months; while in fall–winter, it was 5.1 deaths per 1,000 children. In turn, gastrointestinal mortality killed 4.4 out of every 1,000 children, and the tuberculosis death rate was 1.8 per 1,000 children).

ENDES statistics reveal that, in the period 2015–2018, 53% of deaths among children under five occurred in first month of life. Mortality in the early months of life occurs across all maternal ages, but affects children born to adolescent mothers in greater proportion.

The international literature and the empirical evidence shows that newborn deaths can be due to the susceptibility of adolescent mothers to unwanted pregnancy, premature birth, and physiological risk (Neal, Channon, & Chintsanya, 2018). The physiological factors can include low birth weight, while premature birth can be the result of nutritional insufficiency during pregnancy (Neal *et al.*, 2018). The effect of the mother's age on infant mortality can only be interpreted as biological; that is, related to reproductive maturity (Wolpin, 1997). This is a finding of almost all studies on infant mortality in which maternal age is a determinant, particularly those focusing on low- and middle-income countries (Abir, Agho, Page, Milton, & Dibley, 2015; Mugo, Agho, Zwi, Damundu, & Dibley, 2018).

Along similar lines, Beltran and Grippa (2008) find that neonatal mortality in Peru is related to biological and practical care factors for the mother–child binomial, such as breastfeeding during the first month, institutional birth, and health insurance (Beltran & Grippa, 2008). In addition, these authors observe that socioeconomic determinants such as mother's education and access to health services are important in the antenatal period (Beltran & Grippa, 2008; Dammert, 2003). Above all, maternal education is an essential factor in managing antenatal and postnatal care practices.

## 5. Conclusions

Between 1992 and 2018, Peru's child mortality rate went from 78 for every 1,000 live births to 19 per 1,000—a reduction of 76%.

Moreover, the under-five survival rate in the first month of life improved from 97.4% (1996) to 99.5% (2018), while after 59 months of life, the rate increased from 93.9% to 99% over the same period. But more recently this reduction in child mortality has slowed, while socioeconomic and biological characteristics continue to shape differences in the survival rate.

During the study period (2015–2018), we found that of the total number of deaths among children under five, 53% occurred in the neonatal period, 33% in the postnatal period, and 14% during post-infancy.

In this study, we considered Mosley and Chen's (1984), socioeconomic and proximate determinants of child survival in developing countries to be appropriate for our analysis of mortality among children under five years of age in Peru. Using this approach, we found that the socioeconomic determinants associated with the years of maternal education, the mother's health coverage, and household socioeconomic status are significant predictors of reductions in mortality among children under five.

More specifically, we observed that maternal education, seen as an indicator of human capital that translates into the capabilities and skills required to improve child health, has a substantial impact on child survival; indeed, there were interaction effects with the socioeconomic determinants (maternal education, household socioeconomic status, and healthcare coverage) that influence child survival.

With regard to the proximate determinants, we found that maternal biological characteristics (maternal age, birth intervals, and birth order), as well as environmental factors (sanitation facilities) significantly predict infant mortality.

## 6. Policy recommendations

Public policy intervention in the dimensions or indicators of human wellbeing, such as education, health, and housing, is crucial for improving children's health conditions . Thus, investment in women's education must be a public policy objective. With regard to housing conditions, connection to the public water and sewerage systems should be at the top of the government agenda at the national, regional, and local levels, since delay or a more gradual approach would mean sacrificing the future wellbeing of today's children.

Because the highest percentage of deaths among children under five occur in the first months of life, it is vital that public policy-makers stress monitoring and follow-up of antenatal care (health promotion, diagnosis, and disease prevention) and family planning for women of reproductive age (Abou-ali, 2003). This is because saving children's lives often requires high-quality healthcare services and trained providers. In this regard, good governance is a key factor in reducing the mortality of children under five.

Therefore, the Peruvian government must take into account quality of governance in its decision-making on resource allocation in the health sector. To this end, we suggest that the Ministry of Education coordinate with the National Council for Science, Technology, and Innovation, (Consejo Nacional de Ciencia, Tecnología e Innovación Tecnológica, CONCYTEC) with a view to funding studies that explore whether social programs and other state interventions in the realms of education, health, and housing conditions are evidence-based.

## References

Abir, T., Agho, K. E., Page, A. N., Milton, A. H., & Dibley, M. J. (2015). Risk factors for under-5 mortality: evidence from Bangladesh Demographic and Health Survey, 2004-2011. *BMJ Open*, *5*(e006722), 1-9. Retrieved from https://doi.org/10.1136/bmjopen-2014-006722

Abou-ali, H. (2003). *The effect of water and sanitation on child mortality in Egypt The effect of water and sanitation on child mortality in Egypt* (Working Papers in Economics 112). Gothenburg: University of Gothenburg.

Alsan, M., & Goldin, C. (2019). Watersheds in child mortality: The role of effective water and sewerage infrastructure, 1880–1920. *Journal of Political Economy*, *127*(2), 586. Retrieved from https://doi.org/10.1086/700766

Ayele, D. G., Zewotir, T. T., & Mwambi, H. (2017). Survival analysis of under-five mortality using Cox and frailty models in Ethiopia. *Journal of Health, Population, and Nutrition*, *36*(1), 25. Retrieved from https://doi.org/10.1186/s41043-017-0103-3

Bellido, J. G., Barcellos, C., Barbosa, S., & Bastos, I. (2010). Saneamiento ambiental y mortalidad en niños menores de 5 años por enfermedades de transmisión hídrica en Brasil. *Revista Panamerica de Salud Pública*, *28*(2), 114-120.

Beltrán, A., & Grippa, A. R. (2006). *Políticas efectivas para reducir la mortalidad infantil en el Perú: ¿cómo reducir la mortalidad infantil en las zonas más pobres del país?* Lima: Centro de Investigación de la Universidad del Pacífico. Retrieved from http://repositorio.up.edu.pe/handle/11354/311

Beltrán, A., & Grippa, R. (2008). Políticas efectivas para reducir la mortalidad infantil en el Perú: ¿cómo reducir la mortalidad infantil en las zonas más pobres del país ? *Apuntes. Revista de Ciencias Sociales*, *62*, 5-54. Retrieved from https://doi.org/10.21678/apuntes.62.570

Bicego, G. T., & Ties Boerma, J. (1993). Maternal education and child survival: A comparative study of survey data from 17 countries. *Social Science and Medicine*, *36*(9), 1207-1227. Retrieved from https://doi.org/10.1016/0277-9536(93)90241-U

Biradar, R., Patel, K. K., & Prasad, J. B. (2019). Effect of birth interval and wealth on under-5 child mortality in Nigeria. *Clinical Epidemiology and Global Health*, *7*(2), 234-238. Retrieved from https://doi.org/10.1016/j.cegh.2018.07.006

Breierova, L., & Duflo, E. (2004). *The impact of education on fertility and child mortality:Do fathers really matter less than mothers?* (Working Paper No. 10513). Cambridge: National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w10513%0ANATIONAL

Caldwell, J., & Caldwell, P. (1983). Roles of Women, Families, and Communities in Preventing Illness and Providing Health Services in Developing Countrie*s*. In J. N. Gribble & S. H. Preston (Eds.). *The Epidemiological Transition: Policy and Planning Implication for Developing Countries Workshop Proceedings*. Washington, D.C: National Academies Press (US). Retrieved from https://doi.org/10.1007/978-1-137-40063-5_3

Chilupula, N. F. (2020). *Demographic and Socio-economic Determinants of Child mortality Zambia: Prospects of Dying Before the Fifth Birthday* (Master's thesis). Universidad de Lusaka, Zambia. Retrieved from https://doi.org/10.13140/RG.2.2.29928.62729

Córdova, P., Román, S., & Galvarro, Z. (2018). Mortalidad de la niñez menor de cinco años en Bolivia: análisis de supervivencia y sus factores de riesgo asociados. *Investigación & Desarrollo*, *18*(2), 73-92. Retrieved from https://doi.org/10.23881/idupbo.018.2-5e

Cox, D. R. (1972). Regression Models and Life-Tables. *Journal of the Royal Statistical Society: Series B (Methodological)*, *34*(2), 187-202. Retrieved from https://doi.org/10.1111/j.2517-6161.1972.tb00899.x

Curtis, S. L., Diamond, I., & McDonald, J. W. (1993). Birth Interval and Family Effects on Postneonatal Mortality in Brazil. *Demography*, *30*(1), 33-43. Retrieved from https://doi.org/10.2307/2061861

Dammert, A. (2003). *Acceso a servicios de salud y mortalidad infantil en el Perú*. Lima: Consorcio de Investigación Económica y Social.

Desai, S., & Alva, S. (1998). Maternal education and child health: is there a strong causal relationship? *Demography*, *35*(1), 71-81. Retrieved from https://doi.org/10.2307/3004028

Dietz, K., Gail, M., Krickelberg, K., Samet, J., & Tsiatis, A. (2003). Survival Analysis: Techniques for Censored and Truncated Data. In *Statistics for Biology and Health*. New York: Springer.

Finlay, J. E., Özaltin, E., & Canning, D. (2011). The association of maternal age with infant mortality, child anthropometric failure, diarrhoea and anaemia for first births: Evidence from 55 low- and middle-income countries. *BMJ Open*, *1*(2), 1-24. Retrieved from https://doi.org/10.1136/bmjopen-2011-000226

Fotso, J. C., Cleland, J., Mberu, B., Mutua, M., & Elungata, P. (2013). Birth Spacing And Child Mortality : An Analysis Of Prospective Data From The Nairobi Urban Health And Demographic Surveillance System. *Journal of Biosocial Science*, *45*(6), 779-798. Retrieved from https://doi.org/10.1017/S0021932012000570

Frost, M. B., Forste, R., & Haas, D. W. (2005). Maternal education and child nutritional status in Bolivia: Finding the links. *Social Science and Medicine*, *60*(2), 395-407. Rectrieved from https://doi.org/10.1016/j.socscimed.2004.05.010

Huicho, L., Segura, E. R., Huayanay-Espinoza, C. A., Niño de Guzman, J., Restrepo-Méndez, M. C., Tam, Y., Barros, A. J. D., Victora, C. (2016). Child health and nutrition in Peru within an antipoverty political agenda: A Countdown to 2015 country case study. *The Lancet Global Health*, *4*(6), 414-426. Retrieved from https://doi.org/10.1016/S2214-109X(16)00085-1

Huynen, M. M. T. E., Vollebregt, L., Martens, P., & Benavides, B. M. (2005). The epidemiologic transition in Peru. *Revista Panamericana de Salud Pública*, *17*(1), 51-59.

Iram, U., & Butt, M. S. (2008). Socioeconomic determinants of child mortality in Pakistan: Evidence from sequential probit model. *International Journal of Social Economics*, *35*(1-2), 63-76. Retrieved from https://doi.org/10.1108/03068290810843846

Kaberuka, W., Mugarura, A., Tindyebwa, J., & Bishop, D. S. (2017). Factors determining child mortality in Uganda. *International Journal of Social Economics*, *44*(5), 633-642. Retrieved from https://doi.org/10.1108/IJSE-08-2015-0201

Kanté, A. M., Nathan, R., Jackson, E. F., Levira, F., Helleringer, S., Masanja, H., & Phillips, J. F. (2016). Trends in socioeconomic disparities in a rapid under-five mortality transition: a longitudinal study in the United Republic of Tanzania. *Bulletin of the World Health Organization*, *94*(4), 258-266A. Retrieved from https://doi.org/10.2471/blt.15.154658

Kaplan, E. L., & Meier, P. (1958). Nonparametric Estimation from Incomplete Observations. *Journal of the American Statistical Association*, *94*(446), 496-509. Retrieved from https://doi.org/10.2307/2281868

Kato, T., Yorifuji, T., Yamakawa, M., Inoue, S., Doi, H., Eboshida, A., & Kawachi, I. (2017). Association of maternal age with child health: A Japanese longitudinal study. *PLOS ONE*, *12*(2), 1-11. Retrieved from https://doi.org/10.1371/journal.pone.0172544

Kiross, G., Chojenta, C., Barker, D., Tiruye, T. Y., & Loxton, D. (2019). The effect of maternal education on infant mortality in Ethiopia: A systematic review and meta-analysis. *PLOS ONE*, *14*(7), 1-12. Retrieved from https://doi.org/10.1371/journal.pone.0220076

Mishra, S. K., Ram, B., Singh, A., & Yadav, A. (2017). Birth order. Stage of infancy and infant mortality in India. *Journal of Biosocial Science*, 1-22. Retrieved from https://doi.org/10.1017/S0021932017000487

Mondal, M. N. I., Hossain, M. K., & Ali, M. K. (2017). Factors Influencing Infant and Child Mortality: A Case Study of Rajshahi District, Bangladesh. *Journal of Human Ecology*, *26*(1), 31-39. Retrieved from https://doi.org/10.1080/09709274.2009.11906162

Mosley, H., & Chen, L. C. (1984). An Analytical Framework for the Study of Child Survival in Developing Countries. *Population and Development Review*, *10*(1984), 25-45.

Mugo, N. S., Agho, K. E., Zwi, A. B., Damundu, E. Y., & Dibley, M. J. (2018). Determinants of neonatal, infant and under-five mortality in a war-affected country: analysis of the 2010 Household Health Survey in South Sudan. *BMJ Global Health*, 1-15. Retrieved from https://doi.org/10.1136/bmjgh-2017-000510

Neal, S., Channon, A. A., & Chintsanya, J. (2018). The impact of young maternal age at birth on neonatal mortality: Evidence from 45 low and middle income countries. *PLOS ONE*, *13*(5), 1-16. Retrieved from https://doi.org/10.1371/journal.pone.0195731

Nyinawajambo, M. R. (2018). *Survival Analysis of Time to Event Data An application to child mortality in Sub-Saharan Africa Region using Their Demographic and Health Surveys* (Master{s thesis). Örebro University School of Business, Örebro, Sweden.

Organización Panamericana de la Salud. (2014). *Estrategia de Cooperación con el País: Perú 2014-2019*. Lima: OPS.

Ribeiro, F., Pimenta, R., Lopes, F., Dalmas, J., & Giroto, E. (2014). Extremes of maternal age and child mortality: analysis between 2000 and 2009. *Revista Paulista De Pediatría*, *32*(3), 381-388. Retrieved from www.spsp.org.br

Rosenberg, D. Y. (2018). Political Economy of Infant Mortality Rate: Role of Democracy Versus Good Governance. *International Journal of Health Services*, *48*(3), 435-460. Retrieved from https://doi.org/10.1177/0020731418774226

Rubio, M., Díaz, J. J., & Jaramillo, M. (2009). *El impacto de PARSalud sobre la calidad de la atención de salud materna entre la población indígena*. Banco Interamericano de Desarrollo. Retrieved from http://www.iadb.org/wmsfiles/products/publications/documents/35537789.pdf

Strauss, J., & Thomas, D. (1995). Human Resources: Empirical Modeling of Household and Family Decisions. *Handbook of Development Economics*, *III*(1885–2022).

Sullivan, J., Rutstein, S., & Bicego, G. (1994). *Comparative Studies 15. Infant and Child Mortality*. Maryland: Macro International Inc.

Tam, Y., Huicho, L., Huayanay-Espinoza, C. A., & Restrepo-Méndez, M. C. (2016). Remaining missed opportunities of child survival in Peru: Modelling mortality impact of universal and equitable coverage of proven interventions. *BMC Public Health*, *16*(1), 1-10. Retrieved from https://doi.org/10.1186/s12889-016-3668-7

Tariku, L. (2019). Effect of Preceding Birth Intervals on child mortality in Ethiopia. Evidence from the Demographic and Health Surveys, 2016. *Epidemiology International Journal*, *3*(1), 1-10. Retrieved from https://doi.org/10.23880/eij-16000118

Vikram, K., Desai, S., & Vanneman, R. (2010). *Maternal Education and Child Mortality: Exploring the Pathways of Influence*. College Park: University of Maryland.

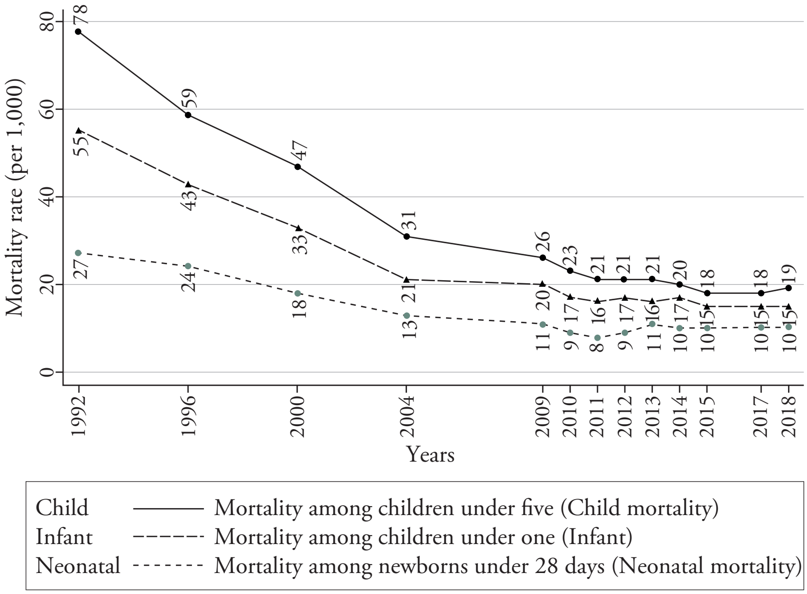
Wolpin, K. I. (1997). Determinants and consequences of the mortality and health of infants and children. *Handbook of Population and Family Economics*, *1*, 483-557. Retrieved from https://doi.org/10.1016/S1574-003X(97)80027-X

World Health Organization (2018). *Goal 3: Ensure healthy lives and promote well-being for all at all ages*. Retrieved from https://www.who.int/health-topics/sustainable-development-goals#tab=tab_2

Yu, F., Yan, Z., Pu, R., Tang, S., Ghose, B., & Huang, R. (2018). Do Mothers with Lower Socioeconomic Status Contribute to the Rate of All-Cause Child Mortality in Kazakhstan? *BioMed Research International*, 1-8. Retrieved from https://doi.org/10.1155/2018/3629109

# Appendices

Appendix 1.
Evolution of mortality rates (number of deaths per 1,000 children five years prior to the survey)




Source: Compiled by authors based on ENDES (1992, 1996, 2000, 2004, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2017, and 2018)

Appendix 2
Neonatal, infant, and childhood mortality by selected characteristics (for the ten years prior to the survey)

| Characteristic selected | Neonatal mortality (MN) | | | Infant mortality (1q0) | | | Child mortality (5q0) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2015-2016 | 2016-2017 | 2017-2018 | 2015-2016 | 2016-2017 | 2017-2018 | 2015-2016 | 2016-2017 | 2017-2018 |
| **Area of residence** | | | | | | | | | |
| Urban | 10 | (8) | (9) | 15 | 13 | 13 | 17 | 16 | 15 |
| Rural | 12 | 13 | 14 | 23 | 22 | 22 | 31 | 29 | 28 |
| **Natural region** | | | | | | | | | |
| Metropolitan Lima 2 | (8) | (8) | (7) | (10) | (10) | (9) | (11) | (11) | (11) |
| Rest of the coast | (8) | (9) | (10) | 13 | 13 | 15 | 17 | 16 | 17 |
| Andes | 14 | 11 | (11) | 25 | 19 | 18 | 30 | 24 | 23 |
| Amazonia | 12 | (12) | (13) | 22 | 21 | 21 | 30 | 29 | 28 |
| **Maternal education** | | | | | | | | | |
| No education | (17) | (15) | (11) | (30) | (23) | (16) | (43) | (32) | (21) |
| Primary | (12) | (14) | (13) | 23 | 24 | 22 | 30 | 31 | 28 |
| Secondary | 12 | 9 | 10 | 17 | 14 | 15 | 20 | 17 | 17 |
| Higher | (7) | (7) | (7) | (9) | 10 | (10) | 11 | 11 | (13) |
| **Wealth quintile** | | | | | | | | | |
| Lower quintile | 13 | (11) | (14) | 25 | 21 | 24 | 34 | 27 | 31 |
| Second quintile | (12) | (13) | (11) | 23 | 20 | 16 | 27 | 26 | 18 |
| Middle quintile | (11) | (8) | (8) | 15 | (12) | 13 | 16 | (14) | 15 |
| Fourth quintile | (8) | (8) | (7) | (11) | (12) | (9) | 12 | (13) | 11 |
| Upper quintile | (6) | (3) | (7) | (8) | (6) | (10) | (11) | (7) | (12) |
| **Selected demographic characteristics** | | | | | | | | | |
| **Child's sex** | | | | | | | | | |
| Male | 13 | 11 | 10 | 19 | 17 | 16 | 24 | 21 | 20 |
| Female | 9 | 8 | 9 | 15 | 13 | 14 | 19 | 17 | 17 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Mother's age at birth** | | | | | | | | | |
| <20 | 13 | 14 | 10 | 24 | 23 | 17 | 29 | 28 | 21 |
| 20–29 | 9 | 7 | 8 | 16 | 12 | 13 | 19 | 15 | 16 |
| 30–39 | 10 | 11 | 12 | 16 | 16 | 16 | 20 | 19 | 20 |
| 40–49 | 17 | 10 | 15 | 22 | 21 | 20 | 26 | 26 | 25 |
| **Birth order** | | | | | | | | | |
| 1st | 9 | 9 | 9 | 14 | 15 | 14 | 17 | 17 | 16 |
| 2nd–3rd | 10 | 9 | 9 | 17 | 14 | 13 | 20 | 17 | 17 |
| 4th–6th | 14 | 10 | 13 | 21 | 16 | 19 | 28 | 22 | 24 |
| 7th and above | 20 | 17 | 15 | 33 | 36 | 29 | 44 | 53 | 43 |
| **Interval since previous birth** | | | | | | | | | |
| <2 | 16 | 14 | 11 | 30 | 26 | 22 | 38 | 33 | 31 |
| 2 years | 12 | 8 | 7 | 22 | 16 | 13 | 27 | 21 | 17 |
| 3 years | 9 | 9 | 10 | 16 | 15 | 15 | 22 | 20 | 18 |
| 4 years and more | 10 | 9 | 10 | 15 | 12 | 15 | 19 | 16 | 18 |
| **Total** | **11** | **10** | **10** | **17** | **15** | **15** | **21** | **19** | **18** |

**( )** Referential data, coefficient of variation above 15%.
**Note.** The rate in parentheses is merely referential; it has a coefficient of variation above 15.0.
**1/** Calculated as the difference between the infant mortality rate and the neonatal mortality rate.
**2/** Comprised of the province of Lima and the constitutional province of Callao
Source: Instituto Nacional de Estadística e Informática–ENDES (2015, 2016, 2017, and 2018)

Appendix 3
Descriptive statistics (part I)

| Notation | Description | Values | Sample | % | Average | Stan. deviation | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| b5 | Dead | 0 | 673 | 1.1% | 0.99 | 0.11 | 0 | 1 |
| | Live | 1 | 59,016 | 98.9% | | | | |
| | | 0 | 1,592 | 2.7% | | | | |
| | | 1 | 1,055 | 1.8% | | | | |
| | | | | 2.7% | | | | |
| | | 3 | 2,401 | 4.0% | | | | |
| | | 4 | 1,921 | 3.2% | | | | |
| | | 5 | 2,019 | 3.4% | | | | |
| | | 6 | 7,874 | 13.2% | | | | |
| | | 7 | 1,943 | 3.3% | 9.218 | 4.135 | 0 | 18 |
| | | 8 | 3,190 | 5.3% | | | | |
| v133 | Years | 9 | 3,765 | 6.3% | | | | |
| | | 10 | 2,197 | 3.7% | | | | |
| | | 11 | 16,037 | 26.9% | | | | |
| | | 12 | 1,567 | 2.6% | | | | |
| | | 13 | 1,841 | 3.1% | | | | |
| | | 14 | 5,617 | 9.4% | | | | |
| | | 15 | 422 | 0.7% | | | | |
| | | 16 | 4,328 | 7.3% | | | | |
| | | 17 | 201 | 0.3% | | | | |
| | | 18 | 109 | 0.2% | | | | |
| | Very poor | 1 | 18,072 | 30.3% | | | | |
| | Poor | 2 | 16,238 | 27.2% | | | | |
| v190 | Middle | 3 | 11,583 | 19.4% | NA | NA | 1 | 5 |
| | Wealthy | 4 | 8,314 | 13.9% | | | | |
| | Very wealthy | 5 | 5,482 | 9.2% | | | | |
| v025 | Urban | 1 | 40,174 | 67.3% | 0.673 | 0.469 | I | 0 |
| | Rural | 0 | 19,515 | 32.7% | | | | |
| | 15–19 years | 1 | 500 | 0.8% | | | | |
| | 20–24 years | 2 | 6,411 | 10.7% | | | | |
| | 25–29 years | 3 | 14,080 | 23.6% | | | | |
| v013 | 30–34 years | 4 | 16,398 | 27.5% | NA | NA | I | 7 |
| | 34–39 years | 5 | 13,604 | 22.8% | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40–44 years | 6 | 7,132 | 12.0% | | | | |
| | 45–49 years | 7 | 1,564 | 2.6% | | | | |
| | Second birth | 2 | 26,588 | 44.5% | | | | |
| Bord | Third birth | 3 | 16,111 | 27.0% | NA | NA | 2 | 4 |
| | Fourth and beyond | 4 | 16,990 | 28.5% | | | | |
| b0 | Single birth | 1 | 58,539 | 98.1% | 0.981 | 0.137 | 0 | I |
| | Multiple births | 0 | 1,150 | 1.9% | | | | |
| v481 | Yes | 1 | 50,726 | 85.0% | 0.850 | 0.357 | 0 | I |
| | No | 0 | 8,963 | 15.0% | | | | |
| b4 | Male | 1 | 30,396 | 50.9% | 0.509 | 0.500 | 0 | I |
| | Female | 0 | 29,293 | 49.1% | | | | |
| v113 | Tap water | 1 | 46,064 | 77.2% | 0.772 | 0.420 | 0 | I |
| | Well water | 0 | 13,625 | 22.8% | | | | |
| | Toilet | 1 | 34,438 | 57.70% | | | | |
| v116 | Well and unimproved_toilet | 2 | 18,479 | 30.96% | NA | NA | I | 3 |
| | No toilet | 3 | 6,769 | 11.34% | | | | |
| Age_15-19 | If in the 15–19 group | 1 | 500 | 0.84% | 0.008 | 0.091 | 0 | I |
| | | 0 | 59,189 | 99.16% | | | | |
| Age_20-24 | If in the 20–24 group | 1 | 6,411 | 10.74% | | | | |
| | | 0 | 53,278 | 89.26% | 0.107 | 0.310 | 0 | I |
| SES_Poor | Yes | 1 | 18,072 | 30.28% | | | | |
| | No | 0 | 41,617 | 69.72% | 0.303 | 0.459 | 0 | I |
| SES_Middle | Yes | 1 | 16,238 | 27.2% | | | | |
| | No | 0 | 43,451 | 72.8% | 0.272 | 0.445 | 0 | I |
| SES_Wealthy | Yes | 1 | 11,583 | 19.41% | | | | |
| | No | 0 | 48,106 | 80.59% | 0.194 | 0.395 | 0 | I |
| SES_Very wealthy | Yes | 1 | 8,314 | 13.93% | | | | |
| | No | 0 | 51,375 | 86.07% | 0.139 | 0.346 | 0 | I |

NA: Not applicable
Source: compiled by authors based on ENDES (2015, 2016, 2017, and 2018)

Appendix 3
Descriptive statistics (part II)

| Notation | Description | Values | Sample | % | Average | Stan. deviation | Min. | Max. |
|---|---|---|---|---|---|---|---|---|
| Sex_female | If female | 1 | 29,293 | 49.08% | 0.491 | 0.500 | 0 | I |
| | If male | 0 | 30,396 | 50.92% | | | | |
| b111 | Less than 1 year | 1 | 240 | 0.40% | NA | NA | I | 3 |
| | Less than 2 years | 2 | 6,996 | 11.72% | | | | |
| | More than 2 years | 3 | 52,453 | 87.88% | | | | |
| Interval≤2years | If less than 2 years | 1 | 6,996 | 11.72% | 0.117 | 0.322 | 0 | 1 |
| | Otherwise | 0 | 52,693 | 88.28% | | | | |
| Interval>2years | If more than 2 years | 1 | 52,453 | 87.88% | 0.879 | 0.326 | 0 | I |
| | Otherwise | 0 | 7,236 | 12.12% | | | | |
| Order_ Birth>3 | If more than 3 years | 1 | 16,990 | 28.46% | 0.285 | 0.451 | 0 | I |
| | Otherwise | 0 | 42,699 | 71.54% | | | | |
| Water_Well | If source is well | 1 | 13,625 | 22.83% | 0.228 | 0.420 | 0 | 1 |
| | Otherwise | 0 | 46,064 | 77.17% | | | | |
| Área_Rural | If rural | 1 | 19,515 | 32.69% | 0.327 | 0.469 | 0 | 1 |
| | Otherwise | 0 | 40,174 | 67.31% | | | | |
| Well/ unimproved_ toilet | If a well or unimproved toilet | I | 18,479 | 30.96 | 0.310 | 0.462 | 0 | 1 |
| | Otherwise | 0 | 41,207 | 69.04% | | | | |
| No_toilet | If no toilet | 1 | 6,769 | 11.34% | 0.113 | 0.317 | 0 | 1 |
| | Otherwise | 0 | 52,917 | 88.66% | | | | |
| Sregion | Metropolitan Lima | 1 | 6,520 | 10.92% | NA | NA | I | 4 |
| | 2:rest coast | 2 | 17,505 | 29.33% | | | | |
| | 3:Andes | 3 | 19,670 | 32.95% | | | | |
| | 4:Amazonia | 4 | 15,994 | 26.80% | | | | |

NA: Not applicable
Source: compiled by authors based on ENDES (2015, 2016, 2017, and 2018)