London School of Economics and Political Science

What matters most for newborns' survival? Patterns of socioeconomic determinants of neonatal and post-neonatal mortality in Bolivia

Filippo Temporin

A thesis submitted to the Department of Social Policy of the London School of Economics and Political Science for the degree of Doctor of Philosophy in Demography/Population Studies

London, November 2019

Declaration of authorship

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I declare that my thesis consists of 43,469 words.

Statement of use of third party for editorial help

I can confirm that my thesis was copy edited for conventions of language, spelling, and grammar by Clare Sandford.

Abstract

This thesis is motivated by the lack of studies on the socioeconomic determinants of neonatal and post-neonatal mortality. While, overall, under-five mortality has decreased substantially over the last decades, the pace of the decline in neonatal mortality rates has been slower, and this trend might be explained by a differential between neonatal and post-neonatal determinants. The aim of this thesis is to analyse the association between a set of socioeconomic factors and infant mortality, focusing on different patterns of association with mortality between the neonatal and post-neonatal periods. Deprivation is the determinant of interest, and is conceptualised as a lack of basic needs related to housing conditions; therefore, non-monetary measures of deprivation based on observed indicators relating to living standards are used. This thesis consists of three studies. The first is a country-level longitudinal study using World Bank data, which finds that poverty and access to clean water are fundamental determinants of both neonatal and post-neonatal mortality. The second study aims to investigate the distribution of deprivation in Bolivia using Demographic and Health Survey data, providing background information for the study of determinants of neonatal and post-neonatal mortality in the country. Bolivia is found to have a high level of segregation in regard to deprivation, and five contextual factors (ethnicity, education, administrative region, distance to urban centres and drought-induced migration) are found to be significantly associated with segregation of deprivation. Finally, a micro-level cross-sectional study explores the mechanisms linking deprivation to neonatal and post-neonatal mortality in Bolivia using Demographic and Health Survey data. After decomposing household-level deprivation into its between- and within-community components, community-level absolute deprivation is found to be a significant predictor of neonatal and post-neonatal mortality. Relative deprivation is found to have a significant association with post-neonatal mortality in Bolivia only when calculated at the municipal level, and not at the community level, while deprivation inequality is not associated with infant mortality. Policies aimed at reducing neonatal and post-neonatal mortality in the context of low- and middle-income countries might be oriented by the findings of this thesis.

Acknowledgements

I would like to thank Professor Arjan Gjonca and Professor Fiona Steele for their extensive and helpful comments, their advice on statistical methods, and their patience throughout the last years.

The study was funded by the ESRC under Grant no. 201557818/1-23-A000. The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the paper.

List of papers

The findings of this thesis have been presented six times at global conferences. Chapters 3 and 4 have been published under the following peer-reviewed journal references:

Temporin, F. (2019). Do Poverty and Economic Inequality Matter for Neonatal Mortality? International Comparison of Macro-Level Deterministic Patterns of Early-Age Mortality. *Statistica*, *79*(2), 157-179.

and

Temporin, F. (2019) A multilevel structural equation modelling approach to study segregation of deprivation: an application to Bolivia. *Quality & Quantity 53, 1-18*

Chapter 5 is under review with the following journal:

Temporin, F. How does deprivation affect early-age mortality? Patterns of socioeconomic determinants of neonatal and post-neonatal mortality in Bolivia, an analysis based on multilevel structural equation modelling (minor revisions required after the second round of reviews, *Demography*)

Table of contents

List of tables

List of figures

List of abbreviations

ANC: Antenatal Care

CFA: Confirmatory Factor Analysis

DHS: Demographic and Health Survey

EFA: Exploratory Factor Analysis

GDP: Gross Domestic Product

GIS: Global Information System

IRT: Item Response Theory

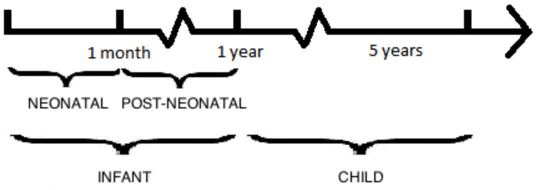
IV: Instrumental Variable

MCMC: Monte Carlo Markov Chain

1. Introduction

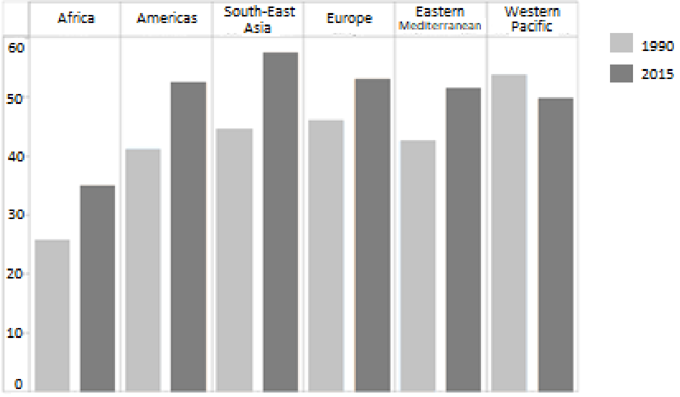
Under-five mortality is divided into infant mortality, occurring within the first year of life, and child mortality, which occurs between the first and the fifth birthdays. The first year of life is further split into the neonatal period, which consists of the first four weeks of life, and the post-neonatal period, from the fifth week to the first birthday (Figure 1.1).

Figure 1.1: Classification of mortality occurring within the first five years of life



The reduction of infant mortality, and especially its neonatal component, represents a major challenge for health systems worldwide. The United Nations' fourth Millennium Development Goal focused on under-five mortality: its target was reducing by two-thirds the global under-five mortality rate between 1990 and 2015. Even though the target was missed, an important achievement has been reached in that the global number of under-five deaths reduced from 12.7 million in 1990 to 5.9 million in 2015 (UNICEF, WHO, World Bank, & UN-DESA Population Division, 2015). However, in the Millennium Development Goal, neonatal mortality was never mentioned, and the decline observed in under-five mortality has not been followed by an equal drop in the amount of deaths occurring within the first month. Although a decrease in neonatal mortality rates (NMRs) has been observed during the last decades, the pace of the decline has been slower than that of infant and child mortality. As a result, neonatal mortality has accounted for a gradually increasing proportion of under-five mortality, from 37% of the total in 1990 to 44% in 2013 (UNICEF et al., 2015). Figure 1.2 shows that this pattern has occurred in every area of the world, except in the Western Pacific (World Health Organization, 2016).

Figure 1.2: Neonatal deaths as percentage of under-five mortality



It can be argued that the increasing proportion of under-five deaths occurring in the neonatal period can be interpreted as a positive sign. Since the main exogenous causes of under-five mortality, such as infections, have been tackled, it follows that the proportion of neonatal deaths has gradually increased. This is mainly due to preterm birth complications, delivery factors and congenital diseases (Black et al., 2010). However, there is evidence that much more can be done in order to prevent neonatal deaths, and to avoid the relative stagnation in their decrease, observed in Figure 1.2. For instance, Knippenberg et al. (2005) estimated that up to 70% of neonatal deaths might be avoided by implementing a set of cost-effective interventions ranging from tetanus toxoid immunisation to breastfeeding.

Neonatal mortality has been labelled a “hidden problem” as a result of the lack of data (Martines et al., 2005) and under-reporting in official statistics (Målqvist, 2011). For instance, there is evidence of a tendency to misreport neonatal deaths as stillbirths, especially in countries where NMRs are an indicator of the quality of health facilities (Aleshina and Redmond, 2005). Another issue is related to the great proportion of deliveries that occur at home, particularly in low- and middle-income countries (Montagu et al., 2011); neonatal and post-neonatal mortality might therefore be biased in official statistics (Målqvist, 2011). A recent call for action has helped to draw international attention to neonatal mortality (Lawn et al., 2005; Martines et al., 2005; Knippenberg et al., 2005). As a result, the neonatal component has been specifically targeted by Sustainable Development Goal 3.2 (Norheim et al., 2015), while only under-five mortality as a whole was mentioned in Millennium Development Goal 4 (Lozano et al., 2011).

1.1) The contributions of this thesis

This thesis analyses the socioeconomic determinants of neonatal and post-neonatal mortality in low- and middle-income countries, with a focus on Bolivia. In particular, the focus is on different patterns of association between deprivation, defined as a lack of basic needs related to housing conditions and living standards, and mortality occurring in the neonatal and post-neonatal periods. This thesis includes three empirical studies, which are presented in Chapters 3, 4, and 5. The aim is to fill the gaps in the literature related to the topics listed below. Both the substantive (C1 and C2) and methodological (C3 and C4) contributions are presented.

C1) Different patterns of the association of deprivation with neonatal mortality, in comparison with post-neonatal mortality

Over the last decades the pace of the decline in neonatal mortality rates has been slower than that of mortality occurring later in life, in many areas of the world (Figure 1.2). While the socioeconomic determinants of infant and child mortality have been analysed extensively in the literature, neonatal mortality requires a more detailed investigation (Neal, 2009). There is some evidence that neonatal and post-neonatal mortality might have different patterns of association with socioeconomic determinants. For instance, some studies have found that poverty (Neal and Falkingham, 2014), environmental factors (Bobak and Leon, 1992), and education (Bicego, 1996; Mahy and Zaba, 2003) have a weaker association with neonatal mortality with respect to post-neonatal mortality, since these factors might need a time span longer than four weeks to have an impact on neonatal mortality. However, the evidence is still insufficient. Different effects of neonatal and post-neonatal determinants might be the reason for the different pace of decline observed in the last decades (Figure 1.2); economic development might have played a stronger role in tackling post-neonatal mortality (Flegg, 1982), explaining the relative stagnation of NMRs.

A lack of studies related to the effects of living standards and housing conditions on neonatal and post-neonatal health outcomes is evident in the literature. Adding evidence on the association between deprivation and the components of infant mortality might shed light on the reasons for the differential trends in neonatal and post-neonatal mortality over the last decades. Two sets of analyses comparing the effects of the determinants of neonatal and post-neonatal mortality are carried out in this thesis, both at the country-level (Chapter 3), as well as at the micro-level, in the context of Bolivia (Chapter 5).

C2) Assessment of relative deprivation and deprivation inequality as predictors of neonatal and post-neonatal mortality

The literature suggests that three manifestations of deprivation can affect infant mortality (Johannesson, 2004). Firstly, the absolute level of household deprivation can be a determinant of infant health (Bruce et al., 2000). Secondly, relative deprivation, defined as the level of a household's deprivation relative to the average level of the group of reference, can also be a hazard for infants' survival (Reagan, 2007). Thirdly, inequality in the distribution of deprivation within a community can also have a contextual effect in determining neonatal and post-neonatal mortality (Wilkinson, 1997). Despite the fact that there is a large body of literature on the association between the absolute level of deprivation and neonatal and post-neonatal mortality, the effect of the other two manifestations of deprivation is not straightforward: few studies address the association between relative deprivation and neonatal and post-neonatal mortality (Lhila and Simon, 2010), while the findings related to deprivation inequality are inconsistent (Lynch et al., 2004; Wilkinson and Pickett, 2006). Moreover, the studies assessing the role of relative deprivation and deprivation inequality are mainly focused on adult health in high-income countries. While 99% of neonatal deaths occur in low- and middle-income countries (Lawn et al., 2005), the great majority of the publications related to neonatal health outcomes were conducted in high-income countries (Kayode et al., 2014).

The micro-level study in this thesis (Chapter 5) involves the simultaneous assessment of relative deprivation and deprivation inequality as predictors of neonatal and post-neonatal mortality in Bolivia, a country with among the highest levels of poverty in Latin America. While Wilkinson (1994) theorised that the distribution of wealth might play a role only in countries where basic needs are met, its effect on health outcomes in low- and middle-income countries has rarely been explored.

Moreover, there is an ongoing debate in relation to the size of the area for which inequality in the distribution of deprivation is calculated, since assessing inequality in geographical regions that are too small might overestimate their homogeneity and lead to a biased association with health outcomes (Wilkinson and Pickett, 2006). The analysis in Chapter 5 sheds light on this issue, by calculating relative deprivation and deprivation inequality in areas of different sizes (communities and municipalities).

C3) Proposal of an alternative to the DHS wealth index for measuring deprivation

This thesis uses non-monetary measures of deprivation, conceptualizing it as a lack of basic needs related to housing conditions and living standards. A recent trend in the study of poverty is to use indicators that assess deprivation from a broader perspective, looking beyond the sole concepts of income and consumption expenditure (Grosse et al., 2005; J. Vandemorteele, 2000), since there is no evidence for which social comparisons are only driven by income (Barnett et al., 2004). The use of asset indices has been increasing in recent years, especially in the context of low- and middle-income countries (Filmer and Scott, 2012). One of the most widely used measures of wealth is the wealth index proposed by the Demographic and Health Survey (DHS) (Rutstein and Johnson, 2004). However, this measure has been extensively criticised in the literature due to methodological (Howe et al., 2008) and conceptual (Kolenikov and Angeles, 2004) issues.

This thesis proposes an improvement in the measurement of deprivation for use with DHS data, by constructing a latent variable for household deprivation. Such a variable is built from items related to housing conditions that can be considered the manifestations of the underlying concept of household deprivation, and overcomes methodological issues that could bias the estimates of its association with the mortality outcome (Múthen, 1997). The latent variable for household deprivation is used in the studies in Chapters 4 and 5, and in both of them the models are compared with those including the DHS wealth index, highlighting the differences in the results when using these two measures.

C4) A generalised modelling approach for the study of deprivation segregation

In Chapter 4, a study on the distribution of deprivation within Bolivia is carried out. Deprivation is therefore an outcome variable in these analyses, following which it is assessed as a determinant of neonatal and post-neonatal mortality in Chapter 5. The study of the segregation of deprivation can provide a tool to determine the economic, social and institutional factors associated with spatial unevenness in the distribution of wealth. In comparison to descriptive measures of poverty segregation, a multilevel structural equation modelling approach allows us to make statistical inferences about segregation, and to assess the extent to which segregation can be explained by contextual variables.

While previous methods in the multilevel structural equation modelling framework have only allowed for binary indicators (Goldstein and Noden, 2003; Leckie et al., 2012), the method proposed here allows for handling a continuous latent variable, measured by multiple correlated indicators. The proposed approach is used to quantify the extent to which household deprivation is clustered within communities in Bolivia and to explore contextual factors associated with between-community differences in deprivation. Moreover, the study of deprivation segregation can be important in informing social policies aimed at tackling the components of infant mortality: if the distribution of deprivation is found to have different gradients of association with neonatal and post-neonatal mortality, age-specific strategies can be made more effective by redistributing resources within countries.

1.2) Main research question and outlines of the three empirical studies

This thesis involves three studies, which are all interrelated and complement each other. Different patterns of association of deprivation with mortality between the neonatal and the post-neonatal periods are analysed both in a country-level longitudinal study (Chapter 3) and in a micro-level cross-sectional study, for the case of Bolivia (Chapter 5). This thesis also involves a study that investigates the factors associated with the segregation of deprivation in Bolivia (Chapter 4).

1.2.1) Chapter 3. Does economic growth matter for neonatal mortality? International comparison of macro-level deterministic patterns of neonatal and post-neonatal mortality

A strong relationship between economic growth and betterments in infant and child mortality rates is well documented in the literature (Pritchett and Summers, 1996; Tandon, 2005; Bhalotra, 2008), but fewer studies have investigated the different patterns within the first year of life, between the neonatal and post-neonatal periods. Among these studies, a stronger association has been found between poverty and mortality in the post-neonatal period compared to the neonatal period (Neal and Falkingham, 2014; Lawn et al., 2005). However, these studies are based on cross-sectional data samples, making it difficult to assess the role of economic growth in neonatal and post-neonatal health outcomes over time and to disentangle its effect from the decrease in NMR and PNMR due to the ongoing demographic transition (Mason, 2005). A gap in the literature is therefore identified, and a study that investigates the relationship between economic growth and the components of infant mortality, assessing potential different effects on neonatal and post-neonatal mortality using panel data is undertaken. This study aims to answer the following research question:

Does per capita GDP have different patterns of association with neonatal mortality and post-neonatal mortality at the national level?

The association between a set of national-level socioeconomic determinants and neonatal and post-neonatal mortality rates is investigated using country-level panel data, focusing on different patterns of association between GDP per capita and mortality between the neonatal and post-neonatal periods. The aim of this study is to bridge the gap in the literature on socioeconomic determinants of neonatal and post-neonatal mortality at the macro level (contribution C1). This study also allows us to assess empirical evidence for the theoretical framework on which the further studies at the micro level are founded. Adding evidence on this topic might shed light on the reasons for the differential trends in neonatal and post-neonatal mortality over the last decades. Using World Bank data, and after implementing a multilevel multiple imputation strategy to impute the missing values of some covariates, two fixed effects models are fitted to predict neonatal and post-neonatal mortality rates. The use of panel data represents a contribution to the literature on socioeconomic determinants of neonatal and post-neonatal mortality since it allows for the assessment of the factors associated with the components of infant mortality longitudinally in the period 2000-2015, while previous studies used cross-sectional data (Neal and Falkingham, 2014).

1.2.2) Chapter 4. A multilevel structural equation modelling approach to understand the factors associated with the clustering of deprivation in Bolivia

This study aims to assess the distribution of deprivation within Bolivia and to quantify the extent of the segregation of deprivation within Bolivian communities. This study informs the findings of the next chapter, which assesses deprivation as a determinant of neonatal and post-neonatal mortality. While Castellanos (2007) undertook a study about the distribution of deprivation in Bolivia using the 2004-05 Living Standards Measurement Study. That survey did not cover the whole country, since only the rural areas of 4 regions out of 9 were taken into consideration. A study covering the whole country is therefore needed to have a clear picture about the extent of deprivation segregation in Bolivia. Moreover, as highlighted in Section 1.1, a methodological gap in the literature was identified, since no multilevel structural equation model can handle continuous latent variables (Goldstein and Noden, 2003; Leckie et al., 2012). The second study therefore aims to describe the patterns of segregation in Bolivia, and to investigate the contextual factors associated with deprivation segregation, since it might be of interest to investigate community characteristics as predictors of the average levels of segregation. The research questions are:

What are the contextual factors associated with the clustering of household deprivation in Bolivian communities?

and

"How can multilevel models analysing segregation be extended to handle a continuous latent variable as an outcome?".

This chapter proposes two main contributions. Firstly, the use of a latent variable for household deprivation allows for a conceptual and methodological improvement in the measurement of deprivation for use with DHS data (contribution C3). Secondly, an extension of the previous research using multilevel models to analyse segregation is proposed to handle a continuous latent variable, measured by multiple binary indicators (contribution C4).

This analysis will help to identify clusters of deprivation and highlight crucial sectors to be developed in order to reduce the unevenness in the distribution of deprivation. Moreover, the findings from this chapter will provide background information for the third study, since it can define how unequal Bolivian communities are, before assessing community-level inequality as a predictor of neonatal and post-neonatal mortality.

1.2.3) Chapter 5. How does deprivation affect neonatal and post-neonatal mortality? Patterns of socioeconomic determinants of neonatal and post-neonatal mortality in Bolivia

As highlighted in Section 1.1, more evidence is needed in the literature to shed light on the effects of relative deprivation and deprivation inequality on the components of infant mortality. The third micro-level study assesses which manifestations of deprivation (its absolute level, its relative level, or its distribution within the community) are significantly associated with neonatal and post-neonatal mortality in Bolivia, adjusting for a set of control variables. The research questions are:

"How important are absolute deprivation, relative deprivation and deprivation inequality in determining neonatal and post-neonatal mortality at the micro level, for the case of Bolivia?"

and

“<u>Does the size of the area for which relative deprivation and deprivation inequality are calculated affect their association with neonatal and post-neonatal mortality?</u>”.

A substantial contribution of this study to the literature is that it will explore the mechanisms linking deprivation to neonatal and post-neonatal mortality (contribution C2). Using data from the 2008 Bolivian DHS, the multilevel SEM models combine a latent variable model for deprivation measured at the household level with a three-level discrete-time event history model for mortality, allowing for disentangling the effect of household- and community-level determinants of neonatal and post-neonatal mortality (contribution C1).

2. Theoretical framework and literature review

2.1) Review of poverty measurement

2.1.1) Assessing poverty beyond monetary measures

An interpretation of poverty in monetary terms has dominated the literature (Alkire et al., 2015). However, since Townsend's (1979) and Sen's (1989) innovative works, there is agreement among researchers that poverty is a multidimensional concept (Atkinsons, 2003). Indeed, at the World Summit on Social Development, held in Copenhagen in March 1995, 117 countries agreed to define absolute poverty as the "condition characterised by severe deprivation of basic human needs, including food, safe drinking water, sanitation facilities, health, shelter, education and information. It depends not only on income but also on access to social services" (Havard, 1995).

Indeed, measuring poverty only from the income dimension has some drawbacks. Income reflects only short-term and transitory flows of money (Nowatzki, 2012), and is therefore unable to evaluate "the capacity of a family to maintain a particular standard of living" (Spilerman, 2000). Monetary measures might not completely reflect the environment in which people live, and the source of the monetary flow is often not taken into account (Piachaud, 1987). Moreover, expenditure does not take into consideration choices made by a consumer (Sen, 2000). Focusing only on low income can therefore be an unreliable indicator of poverty, failing to identify those experiencing deprivation and exclusion (Nolan, 2010).

Sen's (1989) capability approach proposes the perspective of assessing poverty as the impossibility of achieving the functionings people desire, and therefore as a deprivation of people's freedom. Monetary aspects are only one dimension among those describing poverty, and have to be complemented by poor living standards and housing conditions, material deprivation, long-term unemployment, low educational level, and poor health and access to the health system, among other things (Atkinson, 2003). A broad principle that underpins this comprehensive approach to poverty is the ability to overcome difficulties due to shocks to living standards. This concept is therefore related to human and social capital, stores, labour and ownership of assets (Bond and Mukherjee, 2002). While the sole financial dimension is the input of wellbeing, the above-mentioned dimensions can be considered to be the outcomes of the condition of poverty, which indicate what a low income actually involves (Gunter, 2009). It is worth highlighting that there are cases in which the correlation between income and the non-monetary dimensions of poverty is low, as found by Klasen (2000) in South Africa.

2.1.2) Approaches to the measurement of poverty

When measuring poverty, different choices can be made in relation to the selection of the dimensions to be considered, the items used to measure such dimensions, and the structure of the weights to assign (Aaberge and Brandolini, 2015). Regarding the dimensions of poverty, several approaches have been used in the literature. While some measures simultaneously take into account a broad variety of dimensions, ranging from health and access to health-care, working conditions, housing, education, relationships, and environment (Erikson, 1993; Stiglitz et al., 2009), other approaches consider a small subset of them, like the Oxford Multidimensional Poverty Index, which includes only the dimensions of education, health, and living standards (Alkire et al., 2010), or the DHS wealth index, which only takes into account living conditions and ownership of assets (Rutstein and Johnson, 2004). It is worth highlighting that the Living Standards Measurement Study surveys have been created as a tool for measuring poverty from a multidimensional perspective (Grosh and Glewwe, 1998). Once the dimensions have been chosen, a broad range of continuous and categorical indicators can be used. Issues related to the commensurability of the items that are merged into a single measure can arise, which can be addressed by standardizing the original items or by applying ordinal criteria (Aaberge and Brandolini, 2015). It is good practice to assess the degree of correlation between indicators belonging to the same dimension, to assess whether they actually describe the same concept. The weighting methods for aggregating the dimensions can range from assigning the same weights (Alkire et al., 2010), to eliciting the weights after expert consultation (Genest and McConway, 1990), to data-driven methods, depending on the correlation pattern of the responses (Desai and Shah, 1988; Klasen, 2000; Lelli, 2005).

2.1.3) Absolute and relative poverty lines

Two approaches can be used when assessing the level of poverty: the absolute and the relative lines (Foster, 1998). The absolute approach takes into account minimum income or living standard. The target is therefore to give a global threshold beneath which individuals are considered poor. Using monetary measures, the poverty lines of 1.90, 3.20 or 5.50$, expressed in purchasing power parity (PPP), are typical examples of the absolute approach, aiming to express the minimum amount of money in order to provide food sufficient for a basic level of nutrition (World Bank, 2000). Despite its ability to provide international comparisons, this method presents some drawbacks. The definition of a minimum living standard varies over time and space, not only among different geographical areas, but even within the same country.

Furthermore, estimating comparable prices is a difficult task, especially in low-income countries and rural economies (Falkingham and Namazie, 2002). Finally, when considering average country-level measures, a hypothetical decrease could hide a widening in within-country disparities between the poor and the better-off part of the population (Gwatkin et al., 1999).

The second approach to poverty is the assessment of relative lines, characterizing poverty in relation to a given society in a given time. Country-specific formulations of a decent living standard lead to the definition of poverty lines based on a country's average per capita income or consumption. For instance, using monetary measures, widespread relative poverty lines identify poor households as those living on below half of the average income of their country, or in relation to a chosen quantile of the distribution of the population (Haagenars, 2017). The same happens when using non-monetary indices as proxies of individual well-being: people with lower access to services or lower-quality living standards in comparison with the rest of the population are poor in relative terms (Gasparini et al., 2008). A positive aspect of this approach is the contextualization of deprivation: people's relative needs change depending on the customary living conditions of their own background society (Foster, 1998). However, some disadvantages exist, since comparisons over time and space are difficult, and, if the prevalence of poverty is widespread in a given country, a relative threshold could lose significance, being unable to clearly identify the poor (Rutstein and Johnson, 2004). Finally, an evenly-distributed drop in living conditions experienced by the whole population will not change the amount of the poor households in that country (Sen and Hawthorn, 1987).

2.2) Conceptualization of deprivation in this thesis

As seen in Section 2.2.2, a comprehensive approach to the measurement of poverty considers non-monetary dimensions like living standards to complement income-based measures by describing the lack of basic needs (Townsend, 1979; Sen, 1989). In this thesis, household deprivation is conceptualised as a lack of basic needs related to housing conditions, measured from observed indicators related to living standards. Household deprivation measures one of the non-monetary dimensions of poverty identified in the previous section, while the other dimensions are left as control variables. The aim is therefore to assess the net effect of housing conditions and living standards on neonatal and post-neonatal mortality, while accounting for the effect of the other dimensions of poverty. The choice of the items used to measure household deprivation is discussed in Chapters 3 and 4, while the definition of the structure of weights to reduce the dimensionality of the chosen items to a single indicator is described in Chapter 4. As highlighted in Section 1.1, gaps in the literature exist in relation to the association between deprivation and neonatal mortality, especially in low- and middle-income countries (Lhila and Simon, 2010; Kayode et al., 2014).

This approach to the measurement of deprivation related to living standards is similar to that of the Demographic and Health Survey (DHS) wealth index. This indicator is built from a set of items associated with living conditions (availability of electricity, water supply, toilet facilities, flooring, and ownership of a dwelling) and ownership of assets and vehicles (radio, television, telephone, refrigerator, bicycle, motorcycle, automobile, and tractor) (Rutstein and Johnson, 2004). Such items are reduced in their dimensionality to obtain a single continuous indicator by means of principal component analysis, and relative poverty lines are drawn using quintiles of the distribution. The DHS wealth index has several conceptual and methodological drawbacks, which are discussed in Chapter 4.

As in previous studies (Rutstein and Johnson, 2004; Rutstein, 2008) the main assumption is that deprivation is an underlying unobserved variable, and the availability of services and the possession of assets is associated with the relative financial position of a household in its community. A reduction in poverty is therefore assumed to lead to a rise in a household's living standards, with a commensurate improvement in access to electricity, clean water and adequate sanitation, among other aspects, which has a direct impact on children's health (Nandy et al., 2005). To sum up, this thesis belongs to the stream of the literature that assesses poverty from a broader perspective and use non-monetary indicators in measuring the functioning of households (Grosse et al., 2005), and complementing income-based measures by describing the lack of basic needs (J. Vandemoortele, 2000).

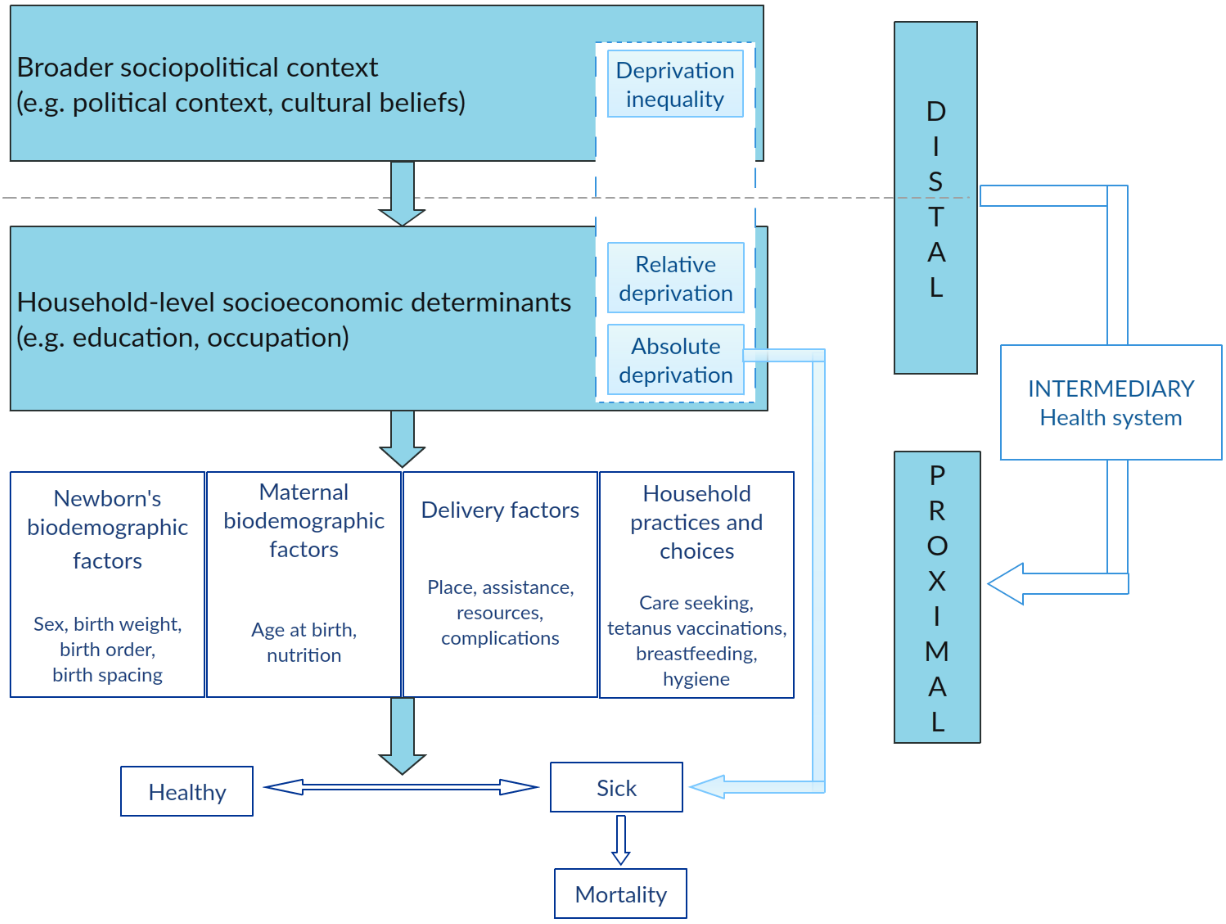
The indicators used in this thesis to measure deprivation are strongly linked with poverty. Inadequate environmental aspects are associated with higher risks of negative health outcomes, lower the likelihood of achieving educational qualifications, and increase a household's living cost. Firstly, poor health outcomes can be fostered by indoor air pollution, caused by a lack of electricity and the use of pollutant fuels (Makdissi et al., 2006), and by poor personal hygiene and environmental pollution associated with low-quality water and sanitation services (Garriga et al., 2013). Secondly, children's educational achievements can be jeopardised by the need to help their mothers seek water or wood, and a lack of toilets in schools can lead students – especially girls – to interrupt their studies (Bosch et al., 2001). Thirdly, a substantial proportion of a household’s income can be spent on fuel and water, especially in those areas lacking connections to the electric grid or water network (ibid). These aspects can lead to a vicious circle by being both a determinant and an outcome of poverty, trapping the poor in their conditions and reproducing the lack of income generation after generation (Falkingham and Nemazie, 2002).

2.3) Theoretical framework for analysing the determinants of neonatal and post-neonatal mortality in low- and middle-income countries

The structure of the theoretical framework for the determinants of neonatal and post-neonatal mortality shown in Figure 2.1 represents a development of Mosley and Chen’s (1984) theoretical framework for child mortality, which was adapted for neonatal mortality by Titaley et al. (2008), and further refined by Neal (2009). This framework aims to represent the determinants of overall infant mortality as a whole, including factors specific to neonatal deaths. A clear distinction between distal socioeconomic and proximate biodemographic determinants (Solar and Irwin, 2007; Kim and Saada, 2013) is made. The reasons for the hierarchical structure among the determinants are highlighted by Victora et al. (1997): “a mistake is to analyse distal and proximate factors as being at the same level, which results in a reduction or elimination of the former’s effects. Factors like family income and parental education [...] referred to as distal determinants [...] are more likely to act through a number of inter-related proximate determinants (intermediate mechanisms)”. The distal determinants are further split into broader socio-political and household-level factors. The three manifestations of deprivation are defined at both levels: inequality at the broader level, while absolute and relative deprivation at the household level. It is worth noting that while deprivation inequality and relative deprivation affect infant health outcomes only mediated though the proximal determinants, absolute deprivation has a direct effect on neonatal and post-neonatal mortality due to environmental aspects such as indoor air pollution and low-quality water and sanitation services (Bruce et al., 2000; Esrey, 1996). Finally, the health system is considered an intermediary determinant between the distal and the proximal factors. As explained later, the use of health services can have a direct effect on the proximal variables, as well as an indirect effect by mediating the influence of the socioeconomic determinants on the mortality outcome (Neal, 2009).

This theoretical framework guides the inclusion of covariates in Chapters 3 and 5. A literature review of the association between each determinant and neonatal and post-neonatal mortality is given below.

Figure 2.1: Theoretical framework for analysing neonatal and post-neonatal mortality in low- and middle-income countries



2.3.1) Socioeconomic determinants of interest

<u>Absolute deprivation</u>: As explained in Section 2.3, this thesis involves the use of non-monetary measures of deprivation related to housing conditions and living standards. Deprivation can be defined as an underlying cause of many infant deaths, due to its effect on several risk factors during the antenatal, neonatal, and post-neonatal periods (McKinnon et al., 2014; Waldmann, 1992). Among the environmental factors, the quality of indoor air, water, and sanitation are strongly associated with overall infant mortality (Bruce et al., 2000; Esrey, 1996). Air pollution might impact infant mortality due to both direct exposure of the child, and prenatal exposure during pregnancy (Proietti, 2012), while poor quality water supply and inadequate sanitation are considered to be the major cause of deaths from diarrhoea (Esrey et

al., 1991; World Health Organization, 2009), which is estimated to be the first cause of post-neonatal mortality (Black et al., 2010).

There is evidence in the literature of a stronger association between housing conditions and mortality in the post-neonatal period compared to the neonatal period. The association between environmental factors and neonatal mortality was found to be weaker than their association with post-neonatal mortality (Bobak and Leon, 1992), or even non-significant (Rahman et al., 2010). Boy et al. (2002) found a positive association between indoor air pollution and low birth weight, which is a risk factor for neonatal mortality (Yasmin et al., 2001). The smaller influence of environmental factors on neonatal mortality could be due to the fact that in the first month of life mortality is more strongly associated with endogenous determinants such as preterm birth complications or congenital diseases (Black et al., 2010; Taskaya and Demirkiran, 2017). Another factor might be the reduced length of exposure to environmental factors of only 28 days. This pattern is consistent with other studies on different patterns of association of economic conditions and mortality occurring in the two periods under investigation: a country-level cross-sectional study found a stronger association between gross national income and post-neonatal mortality in comparison with neonatal mortality in low- and middle-income countries (Neal and Falkingham, 2014), while another study found larger differences in post-neonatal than in neonatal mortality between the richest and poorest quintiles (Lawn et al., 2005).

Finally, absolute deprivation might also be a risk factor for neonatal and post-neonatal mortality when considered as a contextual determinant measured at the community level, due to many aspects such as environmental exposure, housing, and social cohesion (Field et al., 2016; Bonet et al., 2013). Living in a deprived neighbourhood has been found to be associated with perinatal mortality (De Graaf et al., 2012), stillbirth (Vos et al., 2014), preterm birth (O'Campo et al., 2007), and post-neonatal mortality (Guildea et al., 2001). A fundamental determinant related to community-level deprivation might be environmental exposure, whose association with adverse birth outcomes has been found to be significant in several studies (Tsai et al., 2006; Woodruff et al., 2008). Improving environmental factors like extending the electric grid and enhancing latrine facilities and sources of domestic water have been found to have a role in infant birth outcomes in the context of low- and middle-income countries (Patel, 1980; Van de Poel, 2009; Jaadla and Puur, 2016).

Relative deprivation: It has been argued in the literature that the relative level of deprivation might be a better predictor of health outcomes than absolute deprivation (Marmot et al., 1991); the level of a household's wealth should be compared to the level of the reference group when assessing its effect on health (Wilkinson, 1997). In general, the poorer health among more disadvantaged people may be due to the lack of material and social resources (Lynch et al., 2001), and to negative upward social comparisons, which can lead to the corrosion of social cohesion by means of "positional competition and violations of norms of fairness" (Kawachi et al., 2002). Few studies have focused on the relationship between relative deprivation and infant health outcomes (Lhila and Simon 2010), and it is worth noting that all these studies are focused on high-income countries; a gap in the literature regarding the effects of relative deprivation in the context of low- and middle-income countries is evident. While it is reasonable to think that children in their early childhood are unaware of social comparisons (Turley, 2002), relative deprivation could affect their parents (Reagan et al., 2007). Tacke and Waldmann (2013) found relative deprivation to be associated with infant mortality at the country level using differences between income quintiles, both when social comparisons were made with members of similar social classes, as well as with the richest group. In two studies based in the US, higher relative deprivation was found to be significantly associated with higher probabilities of low birth weight, preterm birth (Lhila and Simon, 2010), and intrauterine growth restriction (Reagan et al., 2007). On the other hand, a US study found a non-significant association between relative deprivation and negative child health outcomes, suggesting a stronger effect of absolute income, rather than its relative level (Olson et al., 2010). Reagan (2007) and Lhila and Simon (2010) identified maternal stress as the pathway through which infant health is affected. Stress due to social comparisons could be both an independent risk factor for preterm birth, as well as a cause of smoking (Kramer et al., 2000). Smoking has been addressed as one of the major determinants of intrauterine growth restriction (Kramer et al., 2000) and low birth weight (Shiono and Behrman, 1995). Moreover, other stress-induced characteristics, such as hypertension and anaemia, are associated with intrauterine growth restriction (Mahajan et al., 2004). On the other hand, relative deprivation has been theorised to have a protective effect on health, since households living in areas with a high average level of wealth (leading to upwards social comparisons) might benefit from the presence of collective resources such as infrastructure, environmental quality, and public services, including health-care (Stafford and Marmot, 2003; Miller and Paxson, 2006).

Deprivation inequality: In addition to the absolute and relative levels of deprivation, inequality in the distribution of deprivation might have a contextual effect on health outcomes (Johannesson 2004). The overall quality of public services could be worsened by the segregation of the rich into their own communities, with access to private education and healthcare (Stiglitz 2013). Deprivation inequality fosters the erosion of social cohesion, generating shame, depression, anxiety, crime and violence (Wilkinson 1997). It is worth highlighting the difference between the deprivation-inequality and the relative-deprivation hypotheses. While the former states that inequality in the distribution of deprivation can be a hazard for the whole population and does not only affect people who care about social comparisons, the latter affirms that better-off households may even benefit from living in an unequal society. Inequality is calculated at the community level, by assigning the same value to all households within the same community; while relative deprivation involves different values for each household, since it compares their deprivation with the average level of deprivation of their community.

In the literature, the findings are inconsistent when assessing the effects of inequality on health. This debate can be summarised by two systematic reviews about the relationship between inequality and health carried out by Lynch et al. (2004) and Wilkinson et al. (2006), who drew opposite conclusions. While Lynch at al. (2004) stated that there is “little support for the idea that income inequality is a major, generalisable determinant of population health differences”, Wilkinson et al. (2006) argued that “[the majority of the studies] suggest that health is less good in societies where income differences are bigger”. This difference might be due to the fact that inequality could have an effect on health only in countries where the condition of absolute deprivation is overcome, while absolute material standards could still be the major determinants of mortality in low- and middle-income countries (Wilkinson 1997; Marmot 2005). However, Moore (2006), who used trading patterns and world-system role rather than income to categorise countries, highlighted that the negative effects of income inequality on health might be stronger in peripheral than in non-peripheral countries. Inequality in the distribution of wealth might therefore also have an effect in peripheral countries, whose populations are more vulnerable due to, among other things, neoliberal philosophies and international trade agreements (Coburn, 2000).

Few studies have assessed the association between neonatal mortality and economic inequality, and the association between inequality and neonatal mortality has rarely been compared to the association with mortality occurring later in childhood. Among the studies that have found a positive relationship, Mayer and Sarin (2005) found the state-level Gini coefficient of household income to be associated with higher neonatal mortality in the US when controlling for a set of biodemographic and contextual variables. On the other hand, Szwarcwald et al. (2002) found a non-significant association between income inequality, measured by the within-neighbourhood Gini coefficient of household income, and neonatal mortality in a micro-level study in Rio de Janeiro. Finally, income inequality was found to be positively associated with post-neonatal mortality in high-income countries (Bird, 2014).

2.3.2) Broader socio-political-economic context

The socioeconomic distal determinants are divided hierarchically between the broader political and economic context, and the household-level socioeconomic factors. The broader context includes factors like the political situation and cultural beliefs. Deprivation inequality, which is the only economic factor found at this level, has already been discussed above.

Political context: The political context can have an influence on social policies that directly or indirectly affect maternal and child health, by setting the priorities for health initiatives. This mechanism takes several country-specific forms, and a general trend is difficult to assess (Navarro and Shi, 2001). For instance, the Bolivian health reform has been strongly funded by international credit supplied by the World Bank to the Bolivian government in 1999, which has been possible because of a favourable agreement between the two institutions (World Bank, 2001). The Bolivian health reform has increased the coverage of antenatal care visits and skilled attendant deliveries, and has thus had a direct influence on neonatal outcomes (Pooley, 2008).

Cultural beliefs: Social norms and cultural beliefs can affect infant mortality through their impact on daily behaviours such as nutrition and health-care. Taboos can be imposed on certain foods, and diets can vary widely across ethnic groups: for instance, infant feeding practices like the introduction of pre-lacteal food can exhibit a strong variation depending on cultural beliefs linked to different ethnic groups (De Sa et al., 2013). Cultural beliefs might have an impact on how the child is considered, the treatment of diseases, and health-related behaviours (Huy et al., 2003). Barriers to health-care access might arise for some communities due to a disregard for healing practices, linguistic barriers and geographic isolation (Montenegro and Stephens, 2006). Moreover, the fact that traditions can be antagonistic towards modern practices might foster mistrust towards modern medicine: for instance, Bolivian indigenous women tend to deliver at home rather than in hospitals because of their beliefs about the disposal of the placenta and the use of metal scissors (Kitts, 1996).

2.3.3) Household-level socioeconomic determinants

The four household-level socioeconomic distal factors considered in this study are the absolute and relative deprivation, education, and occupation. While the factors related to deprivation have already been discussed in Section 2.4.1, a brief review of the other determinants is given below.

Education: The relationship between maternal education and neonatal mortality has been found to be strongly negative, in high-income (Arntzen et al., 2008), as well as in low- and middle-income countries (Kamal, 2012). Despite the limited number of studies, the effect of maternal education on neonatal mortality is found to be weaker than on post-neonatal mortality (Bicego, 1996; Kost and Amin, 1992; Mahy and Zaba, 2003). Possible explanations for the link between maternal education and neonatal mortality include more knowledge about complications, adequate access to health services, quality of feeding and household sanitation (Das Gupta, 1990; Buor, 2003; Ogunlesi, 2015). Education can also affect newborn survival through its effect on women’s status within the household and their capability to communicate effectively with health staff (Caldwell, 1979; Karlsen et al., 2011). Moreover, paternal education can have an important role in regard to proximate determinants, in particular delivery and neonatal factors (Arntzen et al., 1993), since fathers’ decisions about their children’s health are substantial especially in contexts of low female emancipation (Sarkadi et al., 2008).

Occupation: Parental occupation is found in the literature to be a significant predictor of birth outcomes like low birth weight and premature delivery, which are associated with neonatal mortality (Parker et al., 1994). In particular, paternal occupation is an important factor, since paternal income is a strong determinant of the socioeconomic status of a household (Thomas, 1990). Previous studies have shown that children born to unemployed fathers are more likely to face neonatal mortality (Titaley et al., 2008), and paternal occupation is significantly associated with low birth weight (Pattenden et al., 1999), stillbirth and preterm delivery (Savitz et al., 1989).

2.3.4) Health system

The health system plays an intermediary role between the distal and the proximal factors, by directly affecting the proximal variables, and mediating the influence of the distal determinants on the mortality outcome. Firstly, the health system has an important impact on antenatal and delivery factors, and can influence household practices and choices. Factors associated with lower neonatal mortality include, among other things, adequate equipment, a suitable environment (Boo and Chor, 1994), availability of transport (Lawn et al., 2009), and presence at a health facility at the time of delivery (Wall et al., 2009). Secondly, the health system can have an intermediate position between the distal and the proximal determinants. For instance, the availability of free services allows poor mothers to attend antenatal care, positively affecting neonatal health outcomes (Awasthi and Pande, 1998).

One of the main channels for tackling neonatal mortality is the maternal health-care system, which in many countries has developed more slowly than preventive and curative child health-care services. Despite the considerable progress in the last decades, only 50% of the mothers worldwide are estimated to have received four or more antenatal care visits, and 30% of them had no skilled attendance during birth (United Nations, 2015). Adequate obstetric care at delivery is estimated to avoid 4 out of 10 neonatal deaths (Lee et al., 2011). Access to health services is influenced by its availability, by financial, geographical and social barriers, by the effectiveness of the performance, and by awareness of the need for trained staff services (Gulliford et al., 2002). In particular in low-income countries, social and financial issues might be relevant factors in preventing maternal access to health services (Adamu and Salihu, 2000).

In addition to neonatal health outcomes, the health system can also have an impact on post-neonatal mortality, by supplying postnatal care packages that are found to have a positive effect on children’s survival during the post-neonatal period (Kerber et al., 2007). On the contrary, low access to health services, or a lack of training in treating the newborns, can have a negative impact on both neonatal and post-neonatal survival (Pitchforth et al., 2006). Moreover, some cultural norms, like the tradition of confining children at home for a period after birth, can jeopardise their post-neonatal survival (Huy et al., 2003).

Finally, when considering public expenditure on the health system, the relationship with children’s health outcomes is not clear: while some studies have found a positive correlation (Bhalotra, 2008; Kim and Lane, 2013; Verhoeven et al., 1999), other analyses have found no significant association (Filmer and Pritchett, 1997; Deolalikar, 2005).

2.3.5) Proximal determinants

Proximal determinants are defined as the mechanisms through which the socioeconomic determinants act on the health outcome. These variables form an intermediate level in the hierarchical structure of the theoretical framework in Figure 2.1, as they are related to both the distal determinants and neonatal mortality. Four proximal determinants are identified: newborn’s biodemographic factors, maternal biodemographic factors, delivery factors, and household practices and choices.

Among the newborn’s biodemographic factors, child's sex has been found in the literature to be associated with neonatal mortality: death rates are higher among boys than girls (Naeye et al., 1971), due to a more marked male biological weakness, which leads to higher vulnerability to infectious diseases (Mahy and Zaba, 2003). Higher male mortality has been observed during the first month after birth, and tends to decrease with age (Bicego, 1996). On the other hand, differences based on the gender of the newborn might arise due to different behaviours among parents in terms of seeking neonatal care and spending on healthcare in some societies (Willis et al., 2009). Birth weight is highly correlated with neonatal mortality. Several studies have documented its association with negative health outcomes (McIntire et al., 1999). NMRs were found to be twice as high among newborns with a low birth weight than among average-weight children in a study set in Bangladesh (Yesmin et al., 2001). Birth order has been found to be correlated with neonatal mortality, since the first-born child has less experienced parents, and fourth or higher order children have higher risks of infection, since they have to compete for resources with their siblings (Edvinsson and Janssens, 2012). In relation to birth spacing, too short and too long intervals between consecutive deliveries can lead to a mother's depletion (Winikoff, 1983); intervals between pregnancies shorter than 18 and longer than 60 months have been found to significantly increase the risk of a negative outcome at delivery (Conde-Agudelo et al., 2006). Many problems may affect children with numerous siblings: competition with brothers and sisters, enhanced infection hazards, and maternal depletion (Kozuki et al., 2013).

The maternal factors include age at birth and nutrition. A U-shaped relationship has been observed between the mother's age at birth and neonatal mortality (Conley and Strully, 2012); children born to mothers aged less than 19 are more likely to have a low birth weight, and to be delivered prematurely, while a maternal age of higher than 30 can lead to a higher risk of neonatal mortality (Arokiasamy and Gautam, 2008). Low maternal weight at delivery is associated with prematurity and delivery complications (Ehrenberg et al., 2003) and maternal mortality factors (Cogswell and Yip, 1995). Maternal obesity increases the risk of stillbirth and perinatal death (Chu et al., 2007).

The delivery factors include place and mode of delivery, assistance and resources available, and complications that occur while giving birth. Place of delivery plays an important role in newborns' mortality, since a significant correlation has been observed between institutional delivery and neonatal mortality (Titaley et al., 2008). Hospitals can handle cases of pneumonia and infections of the respiratory tract, which are among the major causes of neonatal mortality (Black, 2010). A conceptual framework for the determinants of three delays in care-seeking has been developed by Thaddeus and Maine (1994). In chronological order, these delays are related to the time between the identification of an obstetric emergency and the decision to look for care, the subsequent time required to reach a health facility, and finally the time it takes to receive appropriate care once the health facility is reached. In particular, the first delay could be associated with inexperience and a lack of awareness of health issues, or decisions about care seeking depending on gender, poverty, fatalism or previous involvement in institutional care (Målqvist, 2011). In relation to assistance during birth, trained health staff can handle complications in pregnancy, such as hypertensive disorders (Bang et al., 1999). Assistance at birth is correlated with place of delivery: the majority of maternal and neonatal deaths that take place at home are due to a lack of supply of modern obstetric care and skilled birth attendants, which can be found in medical institutions (Koblinsky, 2003).

Finally, among the household practices and choices, care seeking is a fundamental determinant of neonatal and post-neonatal mortality. The frequency of antenatal care (ANC) visits has been found to be negatively correlated with neonatal mortality and complications during deliveries (Neal, 2009). Women receiving ANC are more likely to plan care throughout the whole period pre- and post-delivery, and have a higher exposure to information on a set of topics, from the identification of complications to best practices in newborn care (ibid). One of the most important aspects of ANC is tetanus vaccination, which has been found in the literature to be associated with neonatal and post-neonatal mortality, since reducing infection during birth can avert a significant number of deaths (Awasthi and Pande, 1998). Care seeking is important also after delivering: a home visit carried out by trained health staff within the first two days after birth was found to significantly reduce neonatal mortality in a study based in Bangladesh (Baqui et al., 2009). Continuity of care is important during the whole time span from the antenatal to the childhood period: newborns are exposed to risk from the first days of life, and a lack of a defined postnatal care package can significantly jeopardise their survival also in the post-neonatal period (Kerber et al., 2007). Furthermore, there is some evidence that early Bacillus Calmette–Guérin, a vaccine primarily used against tuberculosis, may have a beneficial effect in the neonatal period (Aaby et al., 2011). Breastfeeding has been found to have a significant association with neonatal mortality (Edmond et al., 2006). The recommended breastfeeding period in order to have a protective effect on mortality ranges from 12 months (Eidelman, 2012) to 24 months after birth (World Health Organization, 2013). Finally, hygiene is fundamental for the prevention of infections: basic home-based care is estimated to reduce neonatal and infant mortality by nearly 50% among the population of rural India (Bang, et al., 1999).

3. Do poverty and economic inequality matter for neonatal mortality? International comparison of macro-level deterministic patterns of neonatal and post-neonatal mortality

3.1) Introduction

As observed in Chapter 1, neonatal mortality has experienced a slower pace of decline than under-five mortality over the last decades (UNICEF et al., 2015). While the socioeconomic determinants of infant and child mortality have been analysed extensively in the literature, neonatal mortality requires a more detailed investigation (Neal, 2009). The study of different patterns of the association between socioeconomic factors and mortality occurring in the neonatal and post-neonatal period has a strong relevance for policy makers: if neonatal mortality has a weaker association with economic development, period-specific strategies have to be implemented to effectively tackle mortality in this age group. Moreover, there is a need for longitudinal studies assessing the role of economic growth over time and disentangling its effect from that of the ongoing demographic transition (Mason, 2005).

A large body of literature exists about the relationship between poverty and child mortality at the macro level, and a positive association between the two variables is well documented (Flegg, 1982; Pritchett and Summers, 1996; Preston and Haines, 2014). However, fewer studies have focused on the socioeconomic determinants of neonatal mortality. Most of the analyses using monetary measures have found a significant association with neonatal health outcomes (Luo et al., 2004; Rip et al., 1987). There is also some evidence of a stronger association between income and post-neonatal mortality (between the age of 28 days and 12 months) than between income and neonatal mortality (Lawn et al., 2005; Neal and Falkingham, 2014). Other studies have found household income to be correlated with under-five mortality, but not with neonatal mortality (Davanzo et al., 1983; Pebley and Stupp, 1987).

This study investigates the association between a set of national-level socioeconomic determinants and neonatal and post-neonatal mortality rates (NMRs and PNMRs) using panel data from different surveys carried out in 79 low- and middle-income countries. Two models including the same covariates are fitted to predict neonatal and post-neonatal mortality rates. The focus is on the potential different patterns of association between per capita GDP and mortality between the neonatal and post-neonatal periods. Aiming to answer the research question: “Does per capita GDP have different patterns of association with neonatal mortality and post-neonatal mortality at the national level?”, this study builds on the work of Neal and

Falkingham (2014), who analysed differences in the patterns of the association between gross national income and mortality occurring in the neonatal and post-neonatal periods. In the context of this thesis, this analysis assesses the empirical support for the socioeconomic determinants of the theoretical framework for the determinants of neonatal and post-neonatal mortality proposed in Chapter 2. These macro-level findings can also be linked with results from the micro-level study in Chapter 5, which analyses the determinants of neonatal and post-neonatal mortality in Bolivia.

In the final part of this study, non-monetary measures of deprivation are used instead of per capita GDP, in order to evaluate their association with neonatal and post-neonatal mortality. As explained in Chapter 2, the aim of this thesis is to assess deprivation looking beyond the concepts of income or consumption expenditure. The national proportions of households with access to electricity, improved water sources, and improved sanitation facilities have been used as the manifestations of deprivation. These three aspects of inadequate housing environment are strongly linked with poverty due to their association with health (Makdissi et al., 2006; Garriga et al., 2013) and education (Bosch et al., 2001), and foster intergenerational poverty transmission (Falkingham and Nemazie, 2002). The chosen variables allow for the identification of extremely deprived households, who lack basic needs for a minimal living standard, and allow for comparisons over time and space. This pragmatic approach to deprivation measurement has practical use in social policies aiming to identify and reduce extreme deprivation.

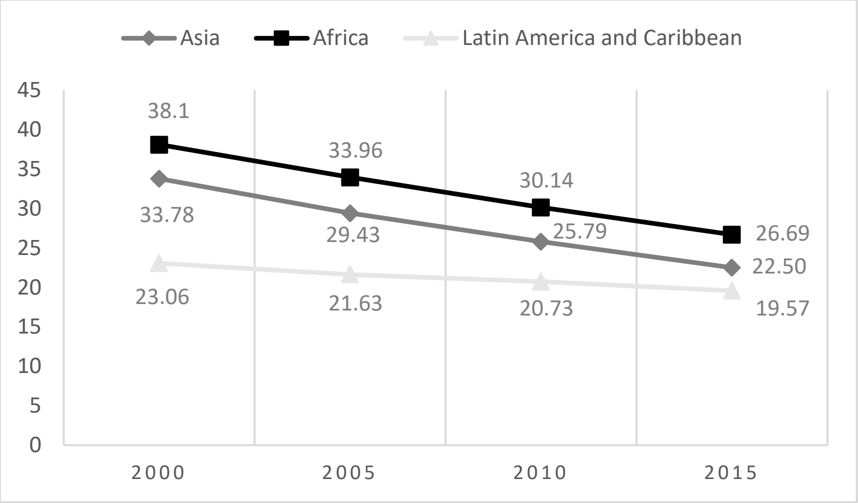
3.2) Global trends in NMR and PNMR

A reduction in NMRs has been observed in every region of the world throughout the last decades, although differences in pace and timing exist across regions. This trend is due to the ongoing demographic transition (Mason, 2005), as well as the fact that under-five mortality has been specifically targeted by Millennium Development Goal 4, fostering policy initiatives and investments that might have reduced NMRs (Murray et al., 2007; Rajaratnam et al., 2010).

According to UNICEF (2018) data, West and Central African countries presented the highest NMR in the world in 2015, with an estimate of 31.4 deaths per 1,000 live births, followed by South Asian countries (28.9 deaths per 1,000 live births). East and Central Asian countries have the fastest pace of reduction of neonatal mortality, with, respectively, a 69.0 and 64.1% reduction between 1990 and 2015, while West and Central African countries have the slowest pace among low- and middle-income countries (35.4%). Latin American countries have a relatively low NMR (9.9 deaths per 1,000 live births).

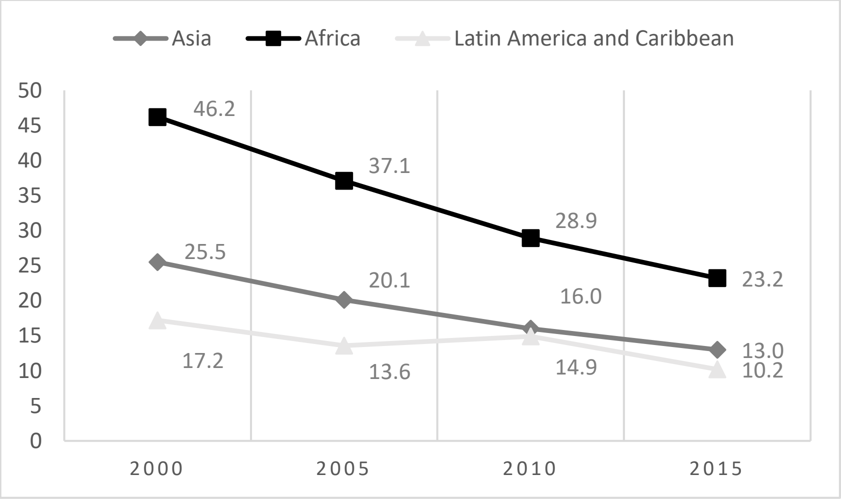
Tables 3.1 and 3.2 present trends in the NMR and PNMR of the countries included in the analyses in this chapter. Due to the fact that only the 79 countries that do not meet the threshold specified by Sustainable Development Goal 3.2 in 2015 were included, the countries have been grouped into the following categories: Asia, Africa and Latin America and Caribbean.

Table 3.1: Neonatal mortality rates (per 1,000 live births), 2000-2015



Source: World Bank. Sample size: 79 countries

Table 3.2: Post-neonatal mortality rates (per 1,000 live births), 2000-2015



Source: World Bank. Sample size: 79 countries

The trends are consistent with the UNICEF (2018) data described above. Overall, the PNMR shows a faster rate of decline in comparison with the NMR in the 2000-2015 period, especially in Asia and Africa, while Latin American and Caribbean countries have a slower but considerable decrease, except in the period 2005-2010, when a small increase is observed. All of the African countries experienced a drop in NMR and PNMR. In particular, Senegal and Ghana made the best progress in their overall infant mortality rates, but with different patterns: while Senegal had among the best performances in the neonatal component (NMR from 39.1 to 21.3), the gains in Ghana were mainly made in the PNMR, since the NMR only decreased from 36.4 to 27.5. Also the great majority of Asian countries showed progress: Bangladesh in particular experienced the best gains in infant mortality as a whole (from 64.0 to 29.7) and in the NMR (from 42.5 to 21.1), while India had among the best gains in the PNMR on the continent (from 21.6 to 10.2). Finally, Latin American countries present a mixed picture: some countries that started with poor performances, like Haiti and Bolivia, had a substantial decrease in their infant mortality rates (respectively, from 74.8 to 52.2 and from 58.5 to 30.5), driven especially by the post-neonatal component, while others experienced a stagnation in the NMR (the Dominican Republic’s NMR decreased from 23.7 to 21.3) or even a worsening (Dominica’s NMRs increased from 10.8 to 23.4).

3.3) Socioeconomic determinants of interest

3.3.1) Per capita GDP

Per capita GDP is a widespread measure of the value of goods and services produced for final consumption in a country, allowing us to measure a country’s economic growth. Its conversion to purchasing power parity (PPP) allows for the calculation of the growth in GDP over time or differences between countries. It has been used as a basic indicator of economic development in many studies (Barro and McCleary, 2003; Sachs and Warner, 1997; Neal, 2009).

As seen in Chapter 2, unfavourable economic conditions have been found to be positively associated with risk factors, acting through environmental aspects (Jain, 1985; S. Rutstein, 2000), nutritional deprivation, both in mothers and children (United Nations Fund for Population et al., 1999), maternal education (Hobcraft et al., 1984; Mahy, 2003), and reduced access to health-care (Lawn et al., 2005). There is evidence in the literature of a stronger association between economic factors and mortality in the post-neonatal period than in the neonatal period (Neal and Falkingham, 2014).

The use of per capita GDP has some limitations, which are fully accepted. Firstly, this measure does not give any indication about the distribution of wealth within a country and does not capture national inequalities (Milanovic, 2016). GDP gives a measure of development in monetary terms, ignoring other dimensions like those associated with social and environmental factors. Finally, GDP might be inaccurate in those countries where the informal economy is strong (Vuletin, 2008).

3.3.2) Non-monetary dimensions of poverty: electricity, water, and sanitation

As explained in Section 1.2, one of the main focuses of this thesis relates to the association between neonatal and post-neonatal mortality and deprivation, conceptualised as a lack of basic needs related to housing conditions and living standards. In this study, three indicators related to access to electricity, clean water, and improved sanitation have been used. These indicators are strongly related to poverty, mainly due to their effect on education and health. Electricity is associated with primary school completion through enabling students to read after sunset (Barnes, 1988), while girls can be reluctant to continue their education due to a lack of toilets in schools (Bosch, 2001). Moreover, indoor air pollution due to the use of polluting fuels instead of electricity, and water-related diseases associated with poor-quality water provision and unimproved sewage systems represent a severe burden for poor households in terms of deaths, malnutrition, and reduced productivity (Komives et al., 2005), forcing the poor into an intergenerational vicious circle of financial deprivation (Falkingham and Nemazie, 2002). Service delivery is a key point in alleviating poverty, since it allows household members to save time dedicated to collecting water and alternative fuels, and therefore increases productivity and raises living standards (Komives et al., 2005). Electricity, water, and sanitation are among the items considered in the DHS wealth index (Rutstein and Johnson, 2004) and the Oxford Multidimensional Poverty Index (Alkire et al., 2010).

A review of the association between the three manifestations of deprivation and neonatal and post-neonatal mortality is presented below.

Access to electricity: This variable is related to health, since a lack of electricity forces households to depend on solid fuels for cooking and heating, which are responsible for high levels of health-damaging pollutants inside houses (Zhang and Smith, 2007; Smith et al., 2011). Indoor air pollution is associated with neonatal and post-neonatal mortality (Bobak and Leon, 1992), and low birth weight (Boy et al., 2002). It is also estimated to be the cause of more than half of premature deaths due to pneumonia among children under-five (World Health Organization, 2016). Moreover, it is also associated with the unavailability of light during the hours of darkness, and of motive power.

Access to clean water: The quality of the water supply is associated with neonatal and post-neonatal mortality, due to exposure to water-borne diseases, particularly those causing diarrhoea (Esrey et al., 1991). Moreover, clean water is related to improved personal hygiene and food preparation hygiene, and a reduced risk of infection (Mertens et al., 1990). Access to clean water has been found to be significantly associated with neonatal and post-neonatal mortality (Macinko, 2006; Fotso et al., 2007).

Access to improved sanitation: Inadequate sanitation is considered to be the major cause of deaths from diarrhoea, together with the unavailability of clean water (World Health Organization, 2009). Improvements in sanitation infrastructures significantly reduced the socioeconomic differences in child mortality due to diarrhoeal diseases between the 19th and 20th centuries (Burström et al., 2005). Less than two-thirds of the global population was estimated to have access to adequate sanitation in 2009 (ibid). Improvements in sanitation conditions are significantly associated with a reduction in neonatal and post-neonatal mortality (Jain, 1985; S. Rutstein, 2000).

3.4) Data and methods

3.4.1) Data and measures

Here, panel country-level data are analysed in order to assess the association between neonatal and post-neonatal mortality and the socioeconomic determinants described above. The data are from the World Bank database (World Bank, 2017). Countries were selected if their NMR in 2015 was higher than the threshold of 12 per 1000 live births, as specified by Sustainable Development Goal 3.2 (Norheim et al., 2015). For each of the selected countries, data from 2000, 2005, 2010 and 2015 were included, for a total of 316 observations from 79 countries:[1]

Afghanistan, Algeria, Angola, Azerbaijan, Bangladesh, Benin, Bhutan, Bolivia, Botswana, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chad, Comoros, Congo Dem. Rep. Congo, Rep., Cote d'Ivoire, Djibouti, Dominica, Dominican Republic, Egypt

---

[1] The observations referring to Somalia have been excluded, since this is the only country with no data for GDP per capita, which needs to be complete since it is a variable that is used as a predictor in the imputation model.

Arab Rep., Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, India, Indonesia, Iraq, Kenya, Kiribati, Lao PDR, Lesotho, Liberia, Madagascar, Malawi, Mali, Marshall Islands, Mauritania, Micronesia, Morocco, Mozambique, Myanmar, Namibia, Nauru, Nepal, Niger, Nigeria, Pakistan, Papua New Guinea, Philippines, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, South Africa, South Sudan, Sudan, Swaziland, Tajikistan, Tanzania, Timor-Leste, Togo, Trinidad & Tobago, Turkmenistan, Tuvalu, Uganda, Uzbekistan, Yemen, Zambia, and Zimbabwe.

The logarithmic transformation of the outcome variable NMR was carried out to obtain an approximately normally-distributed variable (the Shapiro test has p-value <0.01 for NMR, and p-value =0.13 for log(NMR)). Table 3.3 shows the list of variables included in the models. In addition to the socioeconomic determinants, year dummies were included in the model, since part of the temporal variation in NMR and PNMR can be explained by period effects. NMR and PNMR have experienced a decrease over the 15-year observation period in low- and middle-income countries, as seen in Section 3.2.

In addition to the determinant of interest, female education, expenditures on health and rurality are also identified in the literature as factors affecting neonatal and post-neonatal mortality. These variables are those available at the macro level, among the socioeconomic determinants of neonatal mortality included in the theoretical framework described in Section 2.3.

Table 3.4 presents the descriptive statistics of the variables included in the model. As we can observe, some variables have a high proportion of missing data. A multilevel multiple imputation (MI) strategy is discussed in the next section.

Table 3.3: List of variables and sources

Variable	**Description**
NMR	Neonatal mortality rate for the five-year period preceding each survey, excluding month of interview from analysis (logarithmic transformation)
PNMR	Post-neonatal mortality rate by five-year period preceding the survey (logarithmic transformation)
GDPpc	The gross domestic product per capita, based on purchasing power parity, converted to international dollars (logarithmic transformation)
Education	Primary completion rate to the last grade of primary education, calculated as the number of new entrants (enrolments minus repeaters) in the last grade of primary education, regardless of age, divided by the population at the entrance age for the last grade of primary education
Health expenditure	Percentage of national GDP dedicated to public and private health expenditure, covering health services, family planning activities, nutrition activities, and emergency aid. It does not include the provision of water and sanitation
Rural	Percentage of the population living in rural areas, as defined by national statistics offices
Electricity	Percentage of population with access to electricity
Water	Percentage of population using an improved drinking water source, including piped water on premises (a piped household water connection located inside the user's dwelling, plot or yard), public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection
Sanitation	Percentage of population using improved sanitation facilities, including flush (to piped sewer system, septic tank, pit latrines), ventilated improved pit latrine, pit latrine with slab, and composting toilet

Table 3.4: Descriptive statistics and proportion missing for country-year observations

Variable	**Median**	**Min**	**Max**	**Proportion missing**
NMR	28.5	12.8	61.3	0
PNMR	24.8	2.6	92.0	0
GDPpc	2,470.5	419.5	33,777.3	0
Education	68.5	12.7	124.7	40.3
Health expenditure	5.2	0.9	21.9	27.5
Rural	63.3	0.0	91.8	0.3
Electricity	42.7	0.1	100.0	25.9
Water	75.6	28.9	100.0	3.4
Sanitation	38.8	6.6	100.0	5.9

3.4.2) Multilevel multiple imputation for missing data

As seen in Table 3.4, the World Bank database had missing data for some variables, whose missing values were imputed by means of a multilevel MI strategy. It was assumed that these data were missing at random, implying that the value of the variable that was missing was not related to the reason behind its absence (Carpenter and Kenward, 2012). Multiple imputed datasets were created, and the model of interest was fitted to each one. Parameter estimates and standard errors were obtained using Rubin's (1987) rules. A regression coefficient was estimated by the mean of the estimates across the imputed datasets and its standard error combines the within and between imputation variance. A multilevel MI takes into account the multilevel structure of the data, with observations nested within countries, allowing us to obtain reliable estimates from multilevel analyses (Grund et al., 2016). MI has been found to perform better than other approaches for data missing completely at random and data missing at random when the sample size is small (Cheema, 2014), and when the proportion of missing data is high (Schafer and Graham, 2002), even up to 80% (Lee et al., 2011).

The first step of the MI was to specify the imputation model. The only variable added to the imputation model was the mean-centred variable for time was also included in the MI model in order to account for the effects of time on the variables with missing values (Zhang, 2016), since many of them show a clear trend over the 15-year period.

Denote by m_{ij} the value in survey i for country j for the covariate whose missing values we want to impute. The equation for the two-level imputation model is

$$m_{ij} = \beta_0 + \beta_1 t_{ij} + u_{0j} + \varepsilon_{ij}, \tag{3.1}$$

where t_{ij} is the mean-centred variable for time, $u_{0j} \sim N(0, \sigma_u^2)$ is the country random effect representing unmeasured time-invariant characteristics of the jth country, and $\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2)$ is the time-varying error term.

The imputation model was estimated using Monte Carlo Markov chain (MCMC) methods, which simulate a set of parameters at each iteration from the posterior predictive distribution of the missing data (Gelman et al., 2013). Following the Bayesian approach, the missing values were treated as parameters and were estimated at each iteration of the MCMC sampling. All of the variables with missing data were estimated simultaneously by means of multivariate models, ensuring that the relationship between the variables was preserved. In this analysis, the number of burn-in iterations was set to 100,000. After the burn-in phase, 500,000 iterations were run, and the values for every 5,000 iterations were stored to obtain 100 imputed datasets. A high number of imputations is required when the rate of missing data is high (Bodner, 2008; Graham et al., 2007). The potential scale reduction factor (Gelman and Rubin, 1992) is the main tool used to check the convergence of the parameters of the imputation models. The packages *pan* (Schafer, 2001) and *mitml* (Grund et al., 2016) of software R (R Core Team, 2014) were used to run these analyses.

3.4.3) Fixed effect model for mortality rates

The Hausman test suggested that fixed effect models were preferred to random effect models, since 94 of the 100 imputed datasets had a p-value of the Hausman test lower than 0.05. The same model was fitted to predict log(PNMR_{ij}). The model of interest is a fixed effects model for the mortality outcome. Denote by NMR_{ij} the outcome variable measured in the ith (i=1,…,4) survey of the jth (j=1,…,79) country. The equation for the fixed effect model is

$$\log(NMR_{ij}) = \beta_1 \log(GDPpc_{ij}) + \beta_2 Education_{\ ij} +$$

$$+\beta_3 Health.expenditure_{ij} + \beta_4 Rural_{ij} + \beta_5 Year\_2005_i +$$

$$+\beta_6 Year\_2010_i + \beta_7 Year\_2015_i + \gamma_j + \varepsilon_{ij}, \qquad (3.2)$$

where γ_j is the unobserved time-invariant country effect, and $\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2)$ is the error term. The inclusion of time dummies allowed for controlling for time fixed effects, since variation in the outcome was expected to arise from overall time trends, as discussed earlier. Before the analysis, all of the continuous covariates were mean centred. Standardised coefficients were included in Tables 3.5 and 3.6, in order to allow for comparisons of the magnitude of the associations across models. The R package *PLM* (Croissant and Millo, 2008) was used to run these analyses.

3.5) Results

3.5.1) Models including per capita GDP

The two-level imputation model of Equation (3.1) was applied to impute the missing values of the covariates *Education*, *Health expenditure*, and *Rural*. The potential scale reduction factors associated with the parameters of this model suggested that convergence was reached. The parameter with the highest potential scale reduction factor was the intercept variance for Education, with a value of 1.005. This value was below the typical threshold of 1.050, indicating that convergence was achieved.

After inspection of the correlation matrix, all of the covariates were included in the model, since no issue of multicollinearity arose (the strongest correlation was between log(*GDPpc*) and *Education*, with a correlation coefficient ranging from 0.48 to 0.58 in the imputed datasets).

Table 3.5 shows the results of Models 1 and 2, with respectively log(*NMR*) and log(P*NMR*) as the outcomes. log(*GDPpc*) had a strongly significant negative association with both outcomes, with a stronger association with neonatal mortality than with post-neonatal mortality (the standardised coefficients are $\beta^*_{\log(GDP),NMR}$=-0.34 vs $\beta^*_{\log(GDP),PNMR}$=-0.26). Among the other variables, *Education* was strongly significant for both outcomes, while *Health expenditure* and *Rural* were not significant predictors of the components of infant mortality. The adjusted R^2 calculated for each of the imputed datasets ranged from 0.64 to 0.67 for Model 1, and from 0.69 to 0.71 for Model 2.

Table 3.5: Fixed effect country-level regressions of the log neonatal and post-neonatal mortality rates; Models 1 and 2

	Model 1: Outcome log(NMR)		**Model 2: Outcome log(PNMR)**	
Variable	**Standardised coefficient**	**P value**	**Standardised coefficient**	**P value**
log(GDPpc)	-0.34	<0.01	-0.26	<0.01
Education	-0.11	<0.01	-0.08	<0.01
Health expenditure	-0.06	0.27	-0.05	0.30
Rural	0.11	0.49	0.17	0.22
Year 2005	-0.19	<0.01	-0.22	<0.01
Year 2010	-0.39	<0.01	-0.44	<0.01
Year 2015	-0.63	<0.01	-0.66	<0.01

Source: World Bank. Sample size: 79 countries

3.5.2) Models including measures of non-monetary deprivation

Alternative models including three non-monetary measures of deprivation instead of log(*GDPpc*) were also fitted. As discussed earlier, the chosen variables were access to electricity, clean water and improved sanitation. These three variables could be included simultaneously in the models, since their correlation coefficient was not too large (the largest correlation coefficient was that between *Electricity* and *Water*, ranging from 0.63 to 0.67 in the imputed datasets), and no issues of multicollinearity arose. The results are shown in Table 3.6.

Among the three determinants of risk, access to clean water was the only significant predictor of both mortality outcomes. This determinant had a stronger association with neonatal mortality than with post-neonatal mortality (the standardised coefficients are $\beta^{*}_{Water,NMR}$=-0.30 vs $\beta^{*}_{Water,PNMR}$=-0.23). None of the other covariates were significantly associated with the mortality outcomes. As with the previous models, this set of covariates explains the variability in the post-neonatal mortality outcome more than that in the neonatal mortality outcome (the adjusted R^2 calculated on each of the imputed datasets ranged from 0.63 to 0.68 in Model 3, and from 0.69 to 0.72 in Model 4).

Table 3.6: Fixed effect country-level regressions of the log neonatal and post-neonatal mortality rates; Models 3 and 4

Variable	Model 3: Outcome log(NMR)		Model 4: Outcome log(PNMR)	
	Standardised coefficient	P value	Standardised coefficient	P value
Electricity	0.06	0.66	-0.02	0.89
Water	-0.30	<0.01	-0.23	0.01
Sanitation	-0.11	0.48	-0.08	0.53
Education	-0.09	0.03	-0.06	0.06
Health expenditure	-0.05	0.35	-0.04	0.36
Rural	0.05	0.74	0.11	0.43
Year 2005	-0.22	<0.01	-0.24	<0.01
Year 2010	-0.46	<0.01	-0.48	<0.01
Year 2015	-0.73	<0.01	-0.71	<0.01

Source: World Bank. Sample size: 79 countries

3.6) Discussion

In this study, per capita GDP was found to have a strongly significant negative association with both neonatal and post-neonatal mortality outcomes. This result is consistent with a large body of literature on the association between poverty and infant mortality as a whole at the country level (Waldmann, 1992; Baird et al., 2011). Countries with a lower GDP, in general, offer worse access to health services than better-off countries, and households lacking financial resources can face barriers to accessing health services (Peters et al., 2008). In general, a reduction in poverty leads to an improvement in a household's nutritional levels and living standards, factors that have a direct impact on children's health (Scott and Duncan, 2000; Nandy et al., 2005).

Per capita GDP was found to have a stronger association with neonatal mortality than with post-neonatal mortality. This result is not consistent with some of the existing literature. Some cross-sectional studies in low- and middle-income countries have found that income has a stronger association with post-neonatal mortality than with neonatal mortality (Lawn et al., 2005; Neal and Falkingham, 2014). It is reasonable to think that the effects of deprivation need a time span longer than four weeks after birth to be totally expressed, especially if we consider Mosley and Chen's (1984) view of child mortality as the "ultimate consequence of a cumulative series of biological insults rather than the outcome of a single biological event". However, a low per capita GDP might be associated with limited access to antenatal and delivery care services, especially in countries where the gap between private and public health services is significant, which therefore affects neonatal mortality. This aspect is believed to have affected the results of the analysis in this chapter.

Among the non-monetary indicators of deprivation, access to clean water was found to be the only significant predictor of both mortality outcomes. Inadequate water sources have been found to be a major cause of water-borne diseases such as those causing diarrhoea (Fewtrell et al., 2005). Access to clean water had a stronger association with neonatal mortality than with post-neonatal mortality. These results might seem counter-intuitive, since the estimated proportion of diarrhoea-related neonatal mortality has been estimated to be much smaller than diarrhoea-related mortality in the first five years of life (Lawn et al 2005; Boschi-Pinto and Velabit, 2006). We should however mention the impact of an unimproved water supply and sanitation on maternal health during pregnancy, which can affect neonatal mortality (Khan et al., 2011; Manassaram et al., 2007). Access to electricity was not a significant predictor of the components of infant mortality: while this variable has been linked to the use of solid fuels for cooking and heating, thereby impacting indoor air pollution (Bruce et al., 2000), other dimensions of deprivation were more strongly associated with the components of infant mortality in our models. Access to improved sanitation was not associated with the components of infant mortality either: its effects on neonatal and post-neonatal mortality related to exposure to water-borne diseases were probably absorbed by the variable associated with access to clean water.

3.7) Limitations

This study has some limitations in relation to the data and variables used in the models. Firstly, the variables included in the analyses might not fully describe the set of all of the socioeconomic determinants of neonatal and post-neonatal mortality considered in the theoretical framework. Several uncaptured factors – among others, measures of political context, social norms and cultural beliefs – could be the reason for the unexplained heterogeneity in the NMRs and PNMRs. For instance, the percentage of GDP aimed at health expenditure could not be informative about the effectiveness of health services and policies, or about their coverage across the population. Other variables, for instance those measuring country-level economic inequality like the Gini coefficient, presented unacceptable levels of missing values for this sample (83.4%). Moreover, it was not possible to disaggregate the data between urban and rural areas. While in rural areas access to clean water and sanitation might be an indicator of wealth, they represent a more complex issue in urban areas, where they can be associated with risks to health due to higher population density and poor infrastructure (World Health Organization, 2006).

Secondly, in relation to the data referring to neonatal and post-neonatal mortality rates, some issues regarding the quality of the World Bank database exist. This database gathers data from many sources, including the DHS, other modules collected by USAid (Malaria Indicator Surveys, AIDS Indicator Surveys, Interim DHS, and World Fertility Surveys), vital registrations, Multiple Indicators Cluster Surveys and the Census. National-level under-five mortality rates are estimated by means of a Bayesian regression model, and smoothed time series for neonatal mortality rates are derived by means of a separate multilevel statistical model (Alkema and New, 2014). The World Bank's model does not take into account the evolution of HIV/AIDS, and there is no explicit adjustment for neonatal mortality rates in countries with a generalised epidemic (Hill et al., 2012). Another problem is the consistency of the indirect estimates in some low- and middle-income countries: although indirect estimates are generally consistent with direct estimates, substantial differences have been highlighted for countries experiencing either an economic crisis or a delayed demographic transition (Silva, 2012).

3.8) Conclusion

While determinants of infant and child mortality have received broad attention in the literature, the socioeconomic factors impacting neonatal mortality have only recently attracted interest from demographers and health researchers. A decrease in under-five mortality observed globally has not been followed by an equal drop in neonatal deaths (Pathirana, 2016). By making use of World Bank data from different surveys of 79 low- and middle-income countries, this study assessed whether economic growth and housing conditions have different patterns of association with deaths occurring in and after the first month of life, while controlling for potential confounders. Among the determinants of interest, per capita GDP and access to clean water were found to be significant predictors of neonatal and post-neonatal mortality. Both determinants were found here to have a stronger association with neonatal than with post-neonatal mortality. It should be taken into account that the sample analysed in this study contained many countries in which the threshold of absolute deprivation has not been overcome. In such contexts, the absolute level of deprivation is the primary socioeconomic determinant of infant mortality (Wilkinson, 1994; Marmot, 2005). The pragmatic consequences of deprivation are therefore of primary importance for neonatal and post-neonatal mortality. Within this thesis, this study provides an international context for the subsequent chapters, setting out an empirical assessment of the socioeconomic determinants of the theoretical framework for the determinants of neonatal and post-neonatal mortality in low- and middle-income countries described in Chapter 2.

By identifying the macro-level socioeconomic factors associated with neonatal and post-neonatal mortality, this study has implications for health and social policies that aim to reduce neonatal and post-neonatal mortality. Policies oriented towards the extension of a clean water supply can have a positive effect on neonatal and post-neonatal mortality. These findings can partly explain the relative stagnation in NMRs observed over the last decades, in comparison to infant and child mortality (UNICEF et al., 2015).

4. A multilevel structural equation modelling approach to understand the factors associated with the segregation of deprivation in Bolivia

4.1) Introduction

Segregation can be defined as a form of physical separation where population groups are isolated into different neighbourhoods (for the case of residential segregation) or schools (for the case of educational segregation), “shaping the living environment at the neighbourhoods [or school] level” (Kawachi and Berkman, 2003).

The geographical clustering of deprived people is commonly associated with economic, ethnic, or physical segregation, and is the consequence of variation in the characteristics under study across areas. The segregation of deprivation may be related to social exclusion,[2] with important consequences for social and health policies. Among the effects of social exclusion, we can highlight diminished access to public services and decreased opportunities for human capital development. In Bolivia, for instance, social exclusion has been identified as a possible mechanism through which individuals belonging to certain ethnic groups reside in areas that also tend to have lower education and income (Gray-Molina et al., 2002). There is some evidence that the opportunities and even the conduct of people residing in certain neighbourhoods is shaped, among other factors, by the characteristics of their neighbourhood (Jencks and Mayer, 1990). Geographic and social isolation could therefore be among the factors underlying certain social pathologies among the poor (Greene, 1991). The analysis of deprivation and poverty segregation can help to identify the most deprived areas, which are economically and socially isolated from the more developed areas. It can provide a tool to determine the economic, social and institutional factors related to spatial unevenness in the distribution of wealth over the area under investigation. Deprivation and poverty segregation might be particularly suitable for policy interventions related to urban planning at a more local level than the national or regional level (Amarasinghe et al., 2005). Moreover, since a higher mortality rate and higher exposure to infectious diseases are likely to be found in contexts of concentrated deprivation (Fiscella and Franks, 1997; Szwarcwald et al., 2002), reducing the differences in deprivation among communities might also be associated with better health outcomes.

---

[2] Social exclusion is the mechanism through which members of a certain group are denied full access to resources and opportunities that are available to others, associated for instance with housing, employment, or healthcare, and linked to social integration (Silver, 1994)

This chapter aims to answer the following research questions: “What are the contextual factors associated with the clustering of household deprivation in Bolivian communities?” and “How can multilevel models analysing segregation be extended to handle a continuous latent variable as an outcome?”. First, the extent of segregation of deprivation across Bolivian communities is quantified, and then area-level variables are used to explain the variation across communities, while allowing for segregation due to unmeasured area characteristics.

This study builds on the previous use of multilevel modelling, which assessed social segregation in schools and areas using a single binary socioeconomic indicator (Goldstein and Noden, 2003; Leckie et al., 2012). The main contribution of this analysis is that the outcome of interest, household deprivation, is treated as a continuous latent variable, measured by a set of multiple correlated indicators. Multilevel structural equation modelling (SEM) allows the simultaneous creation of a latent variable for household deprivation, and its decomposition into between-community and between-household within-community components to measure the segregation of deprivation. Moreover, multilevel modelling allows us not only to describe patterns of segregation, but also to investigate the contextual factors associated with deprivation segregation, since it might be of interest to examine whether the average levels of segregation vary across communities as a function of community characteristics (Bruch and Atwell 2015). The proposed multilevel SEM is applied here to the study of the segregation of deprivation in Bolivia in 2008 using survey data linked to the Global Information System (GIS) data. By the end of the first decade of the millennium, Bolivia was one of the poorest countries in South America (Population Reference Bureau 2013), and more than half of the population fell below the poverty line, mostly in rural areas (World Bank 2014). Bolivian economic inequality is still great, with a Gini coefficient of 51.4 in 2008 (against an average of 49.9 of the other South American countries). The distribution of wealth within the country was not uniform, with considerable geographic and ethnic dissimilarities (Schroeder 2007).

As discussed in Chapter 2, deprivation is conceptualised as a lack of basic needs related to housing conditions and living standards, rather than monetary measures. The use of asset indices has been increasing recent years, especially in the context of low- and middle-income countries (Filmer and Scott, 2012). An alternative measure to the Demographic and Health Survey (DHS) wealth index is proposed, taking into account only items related to housing conditions with a sufficient degree of correlation among them, which can therefore be considered as manifestations of the underlying concept of household deprivation.

This analysis is meaningful in the context of the whole dissertation, as it is strictly related to the other research questions. For instance, if community-level deprivation is found to have a significant association with neonatal and post-neonatal mortality, policies aimed at reducing mortality should take into account the distribution of deprivation in the area under investigation. Furthermore, if neonatal and post-neonatal mortality have a different gradient of association with the community-level deprivation, age-specific strategies can be made more effective by considering the distribution of deprivation. More specifically, this analysis makes use of community-level covariates to explain the differences in community-level deprivation; the between- and within- community components of deprivation are two of the determinants of neonatal and post-neonatal mortality that will be explored in the analysis in Chapter 5.

4.2) Approaches to the measurement of segregation of poverty and deprivation

4.2.1) Conceptualization of deprivation

As seen in Section 2.3 of this thesis, household deprivation is conceptualised as a lack of basic needs related to living standards and housing conditions. This measure complements monetary indicators by describing the lack of basic needs related to one of the outcomes of poverty (J. Vandemoortele, 2000). Deprivation is assumed to be associated with the relative financial position of a household in its community, and improvements in a household’s living standards are associated with a reduction in poverty. In Sen’s (1989) capability approach framework, this conceptualization of deprivation assesses a household’s ability to participate in their own society and therefore considers poor living standards as a limitation of people’s freedom (Jensen et al., 2003). Living standards and housing conditions are strongly related to poverty, due to their association with health (Garriga et al., 2013) and education (Bosch et al., 2001), leading to the intergenerational transmission of poverty (Falkingham and Nemazie, 2002). This approach is similar to that used in the construction of the DHS wealth index, but a different set of chosen items and different methods allow us to overcome issues in the use of such an index, as described later in Section 4.4. This approach overcomes some of the issues related to the use of income, like the fact that income measures only short-term flows of money (Nowatzki, 2012) and does not consider households’ choices (Sen, 2000), while measuring living standards is a less transitory measure of the conditions of a household. This measure of living standards has been used in previous studies to assess poverty rates for specific population groups (Jensen et al., 2003) and in the study of their effect on health outcomes (Grundy and Holt, 2001; Salmond and Crampton, 2012).

4.2.2) Descriptive segregation measures

The traditional approach in the study of segregation involves the use of descriptive indicators. The most widespread descriptive measure of segregation is the dissimilarity index (Duncan and Duncan, 1955). This index has been widely used in the deprivation and poverty segregation literature (Bibby, 1975; Mershrod, 1981; Napierala and Denton, 2017), including in the only study – to the best of our knowledge – on segregation in Bolivia, which investigated residential segregation in ten Bolivian cities (Gray-Molina et al., 2002). A drawback of the dissimilarity index is that it allows for computing segregation only between two groups. Theil's (1972) information theory index, Bell's (1954) and Lieberson's (1981) isolation indices for multiple populations, and James' (1986) generalised exposure-based segregation index allow the calculation of segregation among multiple groups. Other measures of segregation that are based on the departure of each observation from measures of central tendency are the variance ratio index (Zoloth, 1976), the Atkinson's family of segregation indices (Allison, 1978), and the square root index (Hutchens, 2001). Measures of variation based on the departure of each observation from all other observations, such as the Gini coefficient (Dorfman, 1979), can also be interpreted as measures of segregation (Kim and Jargowsky, 2009). As with the dissimilarity index, the Gini coefficient is related to the Lorenz – or segregation – curve (Gastwirth, 1972). The standardised versions of these indices range from 0 (no segregation, i.e. all areas have the same proportion of population groups) to 1 (complete segregation, i.e. each area is composed of just one of the population groups) (Massey et al., 1996). The descriptive segregation measures described above are "aspatial", meaning that they do not take into account the spatial proximity of the observations (Morrill, 1991). A recent development in the measure of segregation involves the spatial dimension of segregation, for instance by including the length of shared boundaries (Wong, 1993), or by using GIS data (Matthews and Parker, 2013). The gradient of spatial segregation can be measured by spatial autocorrelation (Cliff and Ord, 1973), which has been widely used in the literature (Chakravorty, 1996; Dawkins, 2007; Amara et al., 2016).

The above-mentioned indices are descriptive, meaning that they are based on observed proportions of population groups that include the effect of random sampling variation (Allen et al., 2015). In other words, they fail to take into account the probabilistic component resulting from the sampling process; stochastic variation due to population sampling can bias segregation measurement, especially when small numbers are involved (Kish, 1954; Leckie and Goldstein, 2015). For instance, Leckie et al. (2012) pointed out that the dissimilarity index, which is based on observed rather than underlying proportions, has sources of bias depending on the size of the areas and the underlying proportions; when analysing small areas, the dissimilarity index systematically overestimates segregation, suffering from the upward bias of the null (Allen et al., 2015). Brunch and Mare (2006) highlighted that indices of segregation based on the division of the population into categories based on some threshold, such as the dissimilarity index, are sensitive to changes in the choice of the thresholds. Finally, it is not possible to investigate the factors associated with deprivation segregation when descriptive measures are used (Owen, 2015).

4.2.3) Multilevel modelling for studying segregation

A multilevel model approach overcomes the above-mentioned limitations, by separating the component of the observed proportion that is due to sampling variation. Segregation can be measured by estimating the higher-level variance parameter in the multilevel model (Goldstein and Noden, 2003). This allows the assessment of the proportion of variation in the characteristic of interest that is due to the grouping of individuals within areas: the larger it is, the more segregated the neighbourhoods or schools are. By estimating standard errors, a statistical inference about segregation can be made (ibid). Moreover, multilevel models can be used to explore sources of segregation by including contextual covariates in the models (Leckie et al., 2012).

The first paper in this stream of literature is by Goldstein and Noden (2003), who measured the evenness of the distribution of disadvantaged students across English schools in the period 1994-1999, using a binary variable as the outcome, namely students' eligibility for free school meals. Since then, a growing number of studies using a multilevel approach have appeared in the literature. Three-level models were first used by Leckie et al. (2012) to study social segregation in schools, with students nested within schools nested within London local authorities. They were followed by other researchers, who applied the models to the study of the ethnic distribution within cities (Jones et al., 2015; Leckie and Goldstein, 2015; Manley et al., 2015; Johnston, 2016; Jones et al., 2018a), allowing simultaneous estimation of the micro-

, meso- and macro-effects of segregation. Leckie and Goldstein (2015) and Manley et al. (2015) extended the multilevel binomial logistic regression used in previous work to a multilevel multinomial logistic regression to model segregation by a categorical variable. A multilevel approach in the computation of the dissimilarity index was developed by Harris (2017) and Harris and Owen (2017) to study the residential segregation of students in England. Moreover, multilevel models can be extended to take into account the spatial proximity of areas, by including spatial weights (Jones and Subramanian, 2014) and dependencies between areal units (Dong and Harris, 2015; Jones et al., 2018b).

The present analysis involves a continuous latent dependent variable measured by multiple binary indicators as an outcome, and therefore requires an extension in an SEM framework of the multilevel models used in previous work. An SEM multilevel model is proposed to study segregation of deprivation in Bolivia, in order to quantify the extent of the segregation in the country and to explore contextual factors associated with differences in the mean deprivation across communities.

4.3) Potential explanations for geographical segregation of deprivation in Bolivia

The segregation of deprivation is strictly related to variation across communities. In fact, the higher the between-community variation of the level of deprivation in a country, the higher the level of grouping of deprived people within geographical areas. On the other hand, no between-community variation indicates that no segregation is present in a country. The main aim of this chapter is to explain the segregation of deprivation, by looking at the potential factors associated with the between-community variation in deprivation. Among these, ethnic composition, education, distance to urban centres and drought-induced rural-urban migration could have a central role.

The first factor that may affect the segregation of deprivation is *ethnicity*. According to the 2001 census, the Bolivian population was composed of a predominantly indigenous population: more than 61% of its people were of native origin (INE, 2002), with more than thirty different indigenous groups living in the country. The ethnic distribution is not uniform, with indigenous populations more concentrated in certain areas – mainly the *Altiplano* (high plateau) and *Valle* (valley) regions. These populations have been found in the literature to be more likely to be deprived: the lack of social welfare programmes leads to high vulnerability to shocks such as droughts, floods and hailstorms (Buzaglo and Calzadilla, 2009). Almost the whole indigenous population (97.5%) of the rural areas has been found to be chronically poor (Castellanos, 2007). Ethnicity could therefore be a source of deprivation segregation: since indigenous households are more disadvantaged, the concentration of these households in certain areas could lead to the segregation of deprivation. Ethnicity could also be a factor in fostering urban residential segregation, due to the increase in migration to Bolivian cities experienced over the last decades (Balderrama, 2011).

Education could play a role in explaining the between-community variation in the level of deprivation in the country. The link between parental education and the socioeconomic status of a household is well-established (Cornia, 2014; King and Hill, 1993). Education could also be a contextual factor in determining the unevenness of the distribution of deprivation across Bolivian communities. The average degree of education in a community could set the context for a wide set of socioeconomic factors, including economic disadvantage (Wight et al., 2006) which could lead to the geographical segregation of deprivation. Bolivia had a strong variation in the literacy rate depending on the ethnic group, since there was a marked urban/rural difference, and indigenous origins were associated with lower formal education (Castellanos, 2007; Psacharopoulos, 1993).

Distance to urban centres might also explain deprivation segregation. The study of social segregation in Bolivian urban environments by Gray-Molina et al. (2002) could be extended to rural areas. The main activity in rural areas is farming: peasants are vulnerable to shocks linked to climate change such as droughts (Castellanos, 2007), and the lack of roads might affect peasants' access to the market (Buzaglo and Calzadilla, 2009). Rural areas are also associated with a lack of infrastructure (Andersen, 2002) and basic services like sanitation and availability of clean water (Coa and Ochoa, 2008), creating a setting of a higher mean level of deprivation.

Finally, Bolivia has been subject to natural disasters over the last decades. In particular, *prolonged droughts* have affected the South-West part of the country (Kessler and Stroosnijder, 2006). Agriculture and livestock rely strongly on vegetation resources, the availability of which can be jeopardised by these events: there is evidence that all Bolivian highland vegetation types were impacted by the droughts (Washington-Allen et al., 1998). It has been calculated that, in the period 1953-1993, Bolivia lost 30% of its agricultural productivity, and one of the main reasons for this is related to soil erosion (Benton, 1993). Droughts have fostered migration towards the cities. Bolivia faced a rapid process of urbanisation, either temporary or permanent, between the 1980s and the 2000s (World Bank, 2015). Drought-driven rural-urban migration can lead to the uneven residential sorting of rural migrants within cities, which leads to a rise in the level of urban residential segregation. Moreover, there is some evidence of a recent trend towards migration differentiated by age-group. The main mechanism is related to the fact that young men are gradually excluded from access to agricultural soil, due to the increased unavailability of land (Balderrama, 2011). Lands are usually distributed among the children, but there is evidence of a tendency among young migrant men to refuse their share of the inheritance (Michels, 2011). Beyond the unavailability of agricultural soil, other factors related to this decision are the high cost of inheritance transactions and the relatively higher benefits of urban work in comparison to land ownership (ibid). This selective migration (Borjas and Tienda, 1987) could therefore be another explanation for the segregation of deprivation in Bolivia.

4.4) Statistical methods

4.4.1) Approaches for measuring household deprivation

An index measuring deprivation is an alternative to monetary measures such as income or expenditure, which are often unavailable or unreliable in low- or middle-income countries (Filmer and Scott, 2012). Deprivation can be considered as a concept underlying certain characteristics of living standards, and can be derived from a set of observable items.

As explained in Section 2.2.2, a key point in the creation of a composite index of deprivation is the choice of weights to be assigned to the observed items. Many approaches exist in the literature, ranging from the simple sum of the owned items to more sophisticated data-driven techniques that take into account the extent to which each item discriminates between households' deprivation (Vandemorteele, 2014). Among these composite indicators, the DHS wealth index, obtained from principal component analysis (PCA), is probably the most widespread (Rutstein and Johnson, 2004). In the following sections, a critique of the construction of the DHS wealth index is presented, and a latent variable approach is proposed.

4.4.2) Critique of the DHS wealth index

The DHS wealth index is constructed by means of PCA, a technique that transforms a set of observed correlated items into a set of linearly uncorrelated principal components by means of an orthogonal transformation (Jolliffe, 1986). PCA's major limitation is that it does not take into account the categorical nature of the observed indicators, treating them as continuous, which is analogous to using an OLS regression for the analysis of a categorical outcome (Howe et al., 2008). The wealth index scores are derived from the first principal component, which often explains only a low proportion of the total variation in the observed items (Kolenikov and Angeles, 2004). Moreover, failure to inspect the correlations among the observed items prior to the construction of any index may lead to the inclusion of items with a strong linear dependence (ibid). Finally, using the DHS wealth index as a measure of deprivation in further analyses ignores the measurement error that arises from constructing an index from a set of items.

4.4.3) Rationale for the construction of a latent variable for household deprivation

Latent variables are variables that are not observed directly, but rather are inferred from a set of measured indicators (Bartholomew et al., 2011). Latent variable analysis is a statistical technique that aims to specify a statistical model linking the latent variables to observable items, and to test hypotheses on the latent variables, for instance on their relationship with the indicators, the relationships among latent variables, and their dependence on covariates (ibid). SEM is a latent variable approach that incorporates a model for the relationship between a continuous latent variable and a set of observed items, considered as manifestations of the latent variable (Bartholomew et al., 2011). In this study, a set of observed items relating to housing conditions and living standards are combined into a latent variable for household deprivation.

An SEM is composed of a measurement model and a structural model, which are estimated simultaneously. The measurement model describes the relationship between the observed items and the latent variable. The structural model is a regression of the latent variable on a set of covariates (Bartholomew et al., 2011). In contrast to PCA, the items included in the measurement model of SEM can be binary or polytomous (ibid). Weights are assigned to the items depending on their ability to discriminate between households’ scores on the latent variable. SEM is a model-based method, since it involves assumptions about the distribution of both observed and latent variables, allowing for population inference. By estimating standard errors, SEM also allows for testing hypotheses involving parameters of both the measurement and structural models. An important feature of SEM is that it takes into account the measurement error, which may bias the estimates of the level of segregation within communities. Latent variables do not have a measurement error associated with them, since they are not measured directly; therefore, the association between them and other covariates can be estimated without any bias (Muthén, 1997).

In comparison to the DHS wealth index, a further development of the proposed approach is the selection of the observed items, which is based on an inspection of the correlation matrix of all items. Only items relating to the latent concept of deprivation are included in the measurement model, as explained later in Section 4.6.1.

4.4.4) Measurement model

The measurement model specifies the relationship between the latent variable and the observed items. Denote by y_{rjk} the r^{th} item $(r = 1, \dots, p)$ of household j $(j = 1, \dots, n_k)$, nested within community k $(k = 1, \dots, K)$. Then the logit of the probability that household j in community k owns item r can be expressed as

$$\operatorname{logit}\left(P\left(y_{rjk} = 1 \middle| \eta\right)\right) = \operatorname{logit}\left(\pi_{rjk}(\eta)\right) = \alpha_{r1}\eta_{jk} - \alpha_{r0}, \tag{4.1}$$

where $\eta_{jk} \sim N(0, \sigma_\eta^2)$ is the latent variable for household deprivation and α_{r0} and α_{r1} are, respectively, the difficulty and discrimination parameters. The difficulty parameter α_{r0} indicates how "difficult" it is to own an item, while the discrimination parameter α_{r1} indicates how well the r^{th} item discriminates between households with different scores for deprivation. In order to identify the model, some constraint must be imposed on the item parameters. It is common to constrain one of the α_{r1}s to 1, which sets the scale of the latent variable to be equal to the scale of the chosen item.

4.4.5) Multilevel structural model

In this chapter, the multilevel structural models specify the partitioning of the variance into a between-community component and a within-community between-household component. Of particular interest is the extent to which community variation can be explained by the community-level covariates described earlier. An important characteristic of multilevel SEM is that the creation of the latent outcome variable and the analysis of its between- and within-community components is done simultaneously, while accounting for measurement error (Muthén, 1997).

The structural model specifying the decomposition of the latent variable η_{jk} into its within- and between-community components is

$$\eta_{jk} = \beta_k + u_{jk}^{(hh)}$$

$$\beta_k = \gamma_{00} + u_k^{(PSU)}, \tag{4.2}$$

where $u_{jk}^{(hh)} \sim N(0, \sigma_u^{2\,(hh)})$ is the household residual and $u_k^{(PSU)} \sim N(0, \sigma_u^{2\,(PSU)})$ is the community-level random effect. They represent, respectively, the within-community and between-community components of household deprivation, and their variances $\sigma_u^{2\,(hh)}$ and $\sigma_u^{2\,(PSU)}$ are the within-community and between-community variances.

When including a contextual variable calculated as the mean of a household-level variable $\bar{X}_k$, it is common to include the group mean centred household-level variable, in this case $X_{jk} - \bar{X}_k$. Therefore, the coefficient associated with the group mean centred household-level variable is the within-group effect, while the coefficient associated with $\bar{X}_k$ is the between-group effect, which measures the relationship between the covariate and the outcome at the community level (Snijders and Bosker, 2012; Steele, 2008). Therefore, a model with a community mean of a household variable can be specified as

$$\eta_{jk} = \beta_{0k} + \beta_1(X_{jk} - \bar{X}_k) + \varsigma_{jk}$$

$$\beta_{0k} = \gamma_{00} + \gamma_{01}\bar{X}_k + u_{0k}, \tag{4.3}$$

where $\eta_{jk} \sim N(0, \sigma_\eta^2)$, $\varsigma_{jk} \sim N(0, \sigma_\varsigma^2)$ and $u_{0k} \sim N(0, \tau_{00}^2)$.

The models are fitted by maximum likelihood, and likelihood ratio tests can be used to compare the fit of nested models. The analyses were carried out using the *gsem* function in the Stata software (StataCorp, 2013).

4.4.6) Dissimilarity index

The dissimilarity index is among the most widespread measures of segregation, and quantifies the proportion of one of the population groups that would have to move to different areas in order to reproduce a distribution matching that of the larger areas (Duncan and Duncan, 1955). This index is calculated in this chapter to quantify the level of segregation and compare the results obtained by means of the multilevel structural models described above.

A binary indicator identifying deprived households is needed to calculate the dissimilarity index. Since the latent variable for household deprivation is continuous, the factor scores of the latent variable were obtained from the measurement model without the within-between decomposition of Equation (4.2). Then quintiles of the distribution of such factor scores were calculated, and households belonging to the fifth quintile were considered the most deprived. This approach has been used in previous studies (Rutstein and Johnson, 2004; Rutstein, 2008) to identify the poorest households after calculating the DHS wealth index.

The dissimilarity index is calculated as

$$D = \frac{1}{2}\sum_{k=1}^{K}\left|\frac{u_k}{U} - \frac{v_k}{V}\right| \tag{4.4}$$

where u_k and v_k are the number of, respectively, deprived and non-deprived households in community k $(k = 1, \dots, K)$, and U and V are the total population of, respectively, deprived and non-deprived households in the country.

4.5) Data and measures

4.5.1) The 2008 Bolivian Demographic and Health Survey

The DHS collect data on a broad range of aspects related to health and living conditions. The target population of the DHS is all women of reproductive age (15-49). The DHS uses a probability sample, where the units are selected with a known and nonzero probability to ensure geographical coverage of the entire national territory (US Aid, 2012). In the sampling process, clusters of a standard size of 100 households are identified and mapped in the territory of the country under investigation, and a further selection within each of these selected clusters is made: each of these areal units serves as a primary sample unit. A fixed proportion of those households is selected by systematic sampling, and a face-to-face interview is conducted with all women aged 15-49 who are members of the selected households (US Aid, 2012). In this chapter, primary sample units were considered to be proxies for the respondents' communities, as in previous studies (Uthman et al. 2011; Robson et al. 2012). Communities are therefore defined as clusters of households within a geographical living environment. PSUs have been defined as a consistent measure of community in DHS surveys (Griffiths et al., 2004), and their sample size was demonstrated to meet the optimum size with a tolerable precision loss (Kravdal, 2006). The 2008 Bolivian DHS dataset contains 19,564 households from 999 communities. Among them, 11,361 household have complete records on the ownership of the items related to housing conditions and on the variables included as predictors in the structural model.

4.5.2) Indicators of deprivation

The full set of items related to housing conditions, living standards and owned assets available in the DHS dataset includes: availability of electricity, availability of clean water, type of sanitation, material of the floor, type of cooking fuels, and ownership of refrigerator, radio, television, motorbike, car, telephone, or bicycle. These are the items used in the construction of the DHS wealth index, a composite measure of a household's cumulative living standard (Rutstein and Johnson, 2004).

All of the observed variables were dichotomised in order to simplify the interpretation of the parameters of the models. The categories for sanitation were combined into two groups, reflecting improved and unimproved hygiene. Sewage and septic systems were included in the first group, while open pit and surface water (street or stream) were included in the second (Günther and Fink, 2010). A binary indicator of floor material was used with the categories "adequate floors" (parquet and "machimbre" - tongue and groove joint - carpet, cement, tile, ceramic and bricks) and "mud, dirt and other materials" (Vandemoortele, 2014). Water was considered to be of adequate quality if it was piped into dwellings, yards, and plots, or if its source was a public tap or standpipe, a tube well or borehole, a dug open or protected well, or a protected spring, or if it was rainwater or bottled water, and if all of these sources were within half an hour's walking distance of the respondent's residence. Water was considered low quality if it came from unprotected wells and springs, rivers, dams, lakes, ponds, streams, tanker trucks, or carts with small tanks, or if it was surface water, or if its source was further than half an hour's walk from the home of the person interviewed. This approach reflects the categorisations used in previous research (United Nations, 2005).

4.5.3) Explanatory variables

As highlighted in Section 4.3, there are four main factors that can be linked to the between-community variation in deprivation: ethnicity, education, distance to urban centres and drought-induced migration. These were represented by five explanatory variables: whether the community is mainly indigenous, mean community-level male years in education, administrative region, distance to the closest municipal capital and risk of drought. All of these were measured at the community level.

Table 4.1 provides the source and values of the covariates.

Table 4.1: List of covariates

Variable	**Source**	**Values**
Indigenous village	DHS	Indigenous, Non-indigenous
Male education (years)	DHS	[0.7; 17]
Administrative region	DHS	Beni, Chuquisaca, Cochabamba, La Paz, Oruro, Pando, Potosí, Santa Cruz, Tarija
Distance to the closest municipal capital (km)	GeoBolivia	[0.06; 96.51]
Risk of drought	SINSAAT	Very low, Low, Medium, High

The contextual binary variable *Indigenous* indicates whether a household lives in a community that has a majority of indigenous or non-indigenous villages. The mean level of male education within each community was chosen as a contextual variable to predict the between-community variation in deprivation. For households with more than one adult male (5.97% of the total), the mean value of years of schooling of the males registered at that household was calculated. In general, male education can better explain the level of deprivation of a household: paternal rather than maternal income is a strong determinant of the wealth status of the household (Cornia, 2014; Thomas, 1990). Moreover, in Bolivia's indigenous communities, men are more likely to assume the position of breadwinners (Paulson et al., 1996). In our sample, men were more educated than women, with an average of 8.3 years of education, against 6.9 for women. However, it might be argued that maternal education can have a role in explaining the level of household deprivation, since female headship can be important in single-parent households, including those where the husbands have left to work in other cities or overseas. Therefore, a sensitivity analysis using maternal instead of paternal education was carried out (results in the Appendix in Section 4.10). As explained in Section 4.3, the variable for risk of droughts is a proxy of rural-urban migration triggered by natural disasters. This variable can therefore be a predictor for differences in mean deprivation across communities by leading to the uneven urban residential sorting of rural migrants, which are vulnerable to shocks linked to climate change (Castellanos, 2007).

Three of the variables (education, administrative region and indigenousness) were provided by the DHS, while the other two variables were obtained by linking the GIS location of the centroid of the DHS clusters with other GIS datasets. The distance from the centroid of each DHS cluster to the closest municipal capital was obtained by linking the DHS GIS dataset and the GeoBolivia dataset (GeoBolivia, 2017a), which provides the location of the 339 Bolivian municipal capitals. The distance was calculated using the Haverisine formula[3] (Robusto, 1957). This measure aimed to be a development of the variable for place of residence provided in the DHS dataset, which has only the categories “urban” and “rural”. The distance to the closest municipal capital can provide a better measure of the variation between urban and rural environments, approaching the concept of Woods’ (2003) “urban-rural continuum”. The distance to the closest municipal capital ranged from 0.06 to 96.51 kilometres. The mean distance of the communities labelled as urban in the DHS variable was 3.88 kilometres, while it was 16.84 kilometres for the rural communities. The variable related to risk of drought was created by linking the DHS GIS dataset with the 2002 National System for Early Alert of Food Security (Sistema Nacional de Seguridad Alimentaria Alerta Temprana, SINSAAT) (GeoBolivia, 2017b). This dataset classifies areas into four levels of drought risk, depending on the frequency of drought over the period 1972-2002. Very low risk is defined as one drought or no droughts every fifth year over the 30-year period, low risk is defined as a drought every

---

[3] The Haversine distance does not reflect real distance, especially in a territory like Bolivia, which is highly mountainous in the South-West areas. It is reasonable to think that Bolivians who are willing to reach the closest municipal capital might have to cover longer distances than the great-circle line connecting their village to the target. A better estimate of such a distance would be the walking (or driving) path from each community to the municipal capital. However, no reliable GIS dataset on minor streets and trails has been found. The only available dataset is related to main roads (GeoBolivia, 2013), but this is not specific enough to include all of the walking trails that Bolivians might take. Therefore, the Haversine formula has been considered the best available approximation of the real distance to the closest municipal capital.

fourth year, medium risk means a drought every second year and high risk means four or more droughts every five years.

In the most recent DHS surveys, each community has been georeferenced during the sample listing process. The GIS readers are generally accurate to within less than 15 metres, but the GIS coordinates of each community are randomly displaced due to issues of confidentiality: the error ranges from 0 to 2 kilometres for urban communities and from 0 to 5 kilometres for rural communities (Perez-Heydrich et al., 2013). While cluster displacement might induce large misclassification errors when calculating the distance between clusters' centroids and health facilities or other specific locations (Skiles et al., 2013), the random displacement of the centroid of the communities was unlikely to affect the results of this study. First, the region of each community was directly calculated from DHS, so no issue of displacement arose even when the random error was introduced. Second, the distance to the closest municipal capital was the variable that could be most affected by the random error. Therefore, a sensitivity analysis using the binary variable for urban or rural place of living provided in the DHS dataset instead of the distance to the closest municipal capital was carried out in the Appendix in Section 4.11. Since no substantial difference in the results was observed, the continuous variable for distance to the municipal capital was retained in the models, since it is considered a better approximation of the rural-urban continuum (Woods, 2003). Third, the areas for risk of drought are very large and the risk of displacement of a community seems very low. There are 46 communities within 5 kilometres of the borders between areas that have different risk of drought (Figure 4.3 in the Appendix in Section 4.12). A sensitivity analysis was carried out in the Appendix in Section 4.12, changing the categorisation of these communities to the area of risk of drought they might have been misplaced from; no substantial difference was found in the results.

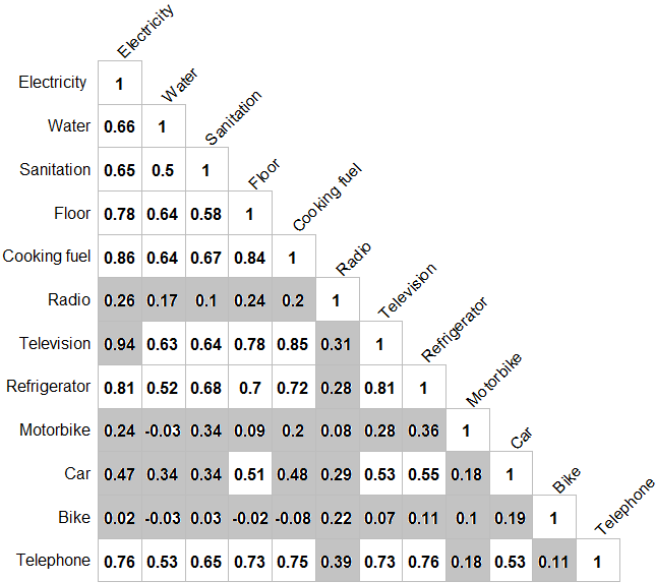
4.6) Construction of the latent variable for household deprivation

4.6.1) Selection of deprivation indicators

The full set of 12 items available in the DHS dataset includes *Electricity*, *Water*, *Sanitation*, *Floor*, *Cooking fuels*, *Radio*, *Television*, *Refrigerator*, *Motorbike*, *Bicycle*, *Car* and *Telephone*. They are considered by the DHS as an appropriate set of items to measure deprivation, since they are the observed manifestation of the level of wealth of a household, and they provide information both on the living environment (the first five items), and on assets or possessions (the last seven items) (Rutstein and Johnson, 2004).

The aim of the investigation of the correlation matrix was to select the observed items used to construct the latent variable, in order to avoid multicollinearity and to have a coherent set of indicators measuring household deprivation. Tetrachoric correlations estimate the correlation between two theorised normally distributed latent variables from two observed binary variables (Divgi, 1979). With the aim of analysing a unique latent variable for household deprivation, the aforementioned observed variables were selected according to their tetrachoric correlations. Only pairs of items with a correlation between 0.5 and 0.9 (those in white in Table 4.2) were considered, in order to retain items measuring the same latent concept, but which were not too highly correlated.

Table 4.2: Tetrachoric correlation matrix, all items



	Electricity	Water	Sanitation	Floor	Cooking fuel	Radio	Television	Refrigerator	Motorbike	Car	Bike	Telephone
Electricity	1											
Water	0.66	1										
Sanitation	0.65	0.5	1									
Floor	0.78	0.64	0.58	1								
Cooking fuel	0.86	0.64	0.67	0.84	1							
Radio	0.26	0.17	0.1	0.24	0.2	1						
Television	0.94	0.63	0.64	0.78	0.85	0.31	1					
Refrigerator	0.81	0.52	0.68	0.7	0.72	0.28	0.81	1				
Motorbike	0.24	-0.03	0.34	0.09	0.2	0.08	0.28	0.36	1			
Car	0.47	0.34	0.34	0.51	0.48	0.29	0.53	0.55	0.18	1		
Bike	0.02	-0.03	0.03	-0.02	-0.08	0.22	0.07	0.11	0.1	0.19	1	
Telephone	0.76	0.53	0.65	0.73	0.75	0.39	0.73	0.76	0.18	0.53	0.11	1

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

The items *Bicycle*, *Motorbike*, *Car*, and *Radio* showed a weak tetrachoric correlation with the rest of the items, and were therefore excluded from the measurement model. Although the correlations between *Television*, *Telephone* and the retained items were sufficiently strong, they were excluded from the measurement model on a theoretical basis. These items cannot be considered as basic needs in the context of a low-income country such as Bolivia; similar to relative poverty, deprivation is a relative concept, and as such it depends on the society (Runciman, 1966). For example, while a household that does not own a telephone in a high-income country can be considered deprived, that is not the case in Bolivia. On the other hand, *Refrigerator* was the only item retained in the measurement model. Not owning a refrigerator has commonly been considered as a lack of basic needs in the context of high-income countries (Townsend, 1979). Its importance as a manifestation of deprivation can be extended to low- or middle-income countries, due to its strong association with health outcomes. By allowing us to keep food fresh, a refrigerator can indeed be related to hygiene and diseases (Lagendijk et al., 2008).

Therefore, the six items selected for the measurement model of household deprivation were *Electricity*, *Water*, *Sanitation*, *Floor*, *Cooking fuel* and *Refrigerator*. These items had a tetrachoric correlation higher than 0.5, suggesting that they are manifestations of the same underlying concept.

4.6.2) Measurement model for household deprivation

The measurement model specified earlier (Equation (4.1)) can be interpreted as a single-level model. The total variance of the latent variable σ_η^2 was estimated as 19.15. The Spearman rank correlation with the DHS wealth index was high in the single-level latent variable, with a value of 0.92. This result is consistent with previous attempts to construct a latent variable for wealth (Vandemoortele, 2014).

Note that the discrimination parameter related to the item *Electricity* was constrained to 1 for identification. As can be seen in Table 4.3, *Cooking fuel* and *Electricity* were the items that best discriminated between households with different deprivation scores, while *Water* and *Sanitation* had the least discriminatory power. Therefore, having electricity discerned household deprivation better than, for instance, having clean water. Moreover, *Water* and *Sanitation* were the most likely items to be owned (those with lower values in the difficulty parameters), while *Cooking fuel* was the least likely.

Table 4.3: Discrimination and difficulty parameters from the measurement model for deprivation

Item	**Discr. (α_{r1})**	**SE (α_{r1})**	**Diff. (α_{r0})**	**SE (α_{r0})**
Electricity	1.00	(constrained)	-4.05	0.12
Water	0.41	0.02	-6.39	0.06
Sanitation	0.43	0.02	-3.91	0.04
Floor	0.72	0.04	-3.00	0.07
Cooking fuel	1.02	0.06	-2.32	0.36
Refrigerator	0.57	0.03	1.86	0.04

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

4.7) Results

4.7.1) Empty multilevel model

The aim of the multilevel structural models (Equations (4.2) and (4.3)) was to analyse the distribution of the latent variable for household deprivation between and within Bolivian communities. In the multilevel model, the between- and within-community variance components were, respectively, 19.51 and 1.77. The intra-community correlation, that is the proportion of variation in the latent variable explained by the grouping of households within communities, allowed an assessment of the level of segregation: a high level of community-level variance reflects substantial differences in household deprivation across communities (Leckie et al. 2012). For this model, a high proportion of variation in the latent variable (around 92%) was due to the grouping of households within communities. A likelihood-ratio test favoured the empty multilevel model over the single-level model ($X^2 = 10279.17$, d.f.=1).

The dissimilarity index was also calculated for this sample. As explained in Section 4.4.6, deprived households were identified as those belonging to the fifth quintile of the distribution of the factor scores of the latent variable for household deprivation. The dissimilarity index calculated on the whole country was equal to 0.51, while, when calculated within departments, the dissimilarity index ranged from 0.26 in Beni to 0.56 in Oruro.

A comparison between the selected SEM model and a model including the continuous DHS wealth index was also made, focusing on the differences in the partitioning of the variance. Using the DHS wealth index, the between-community variance was 0.82 and the within-community variance was 0.19, giving an intra-community correlation of 0.81 (Table 4.4).

Table 4.4: Variance decomposition of the latent variable for household deprivation, all models

	Between-community variance	SE	Within-community variance	SE	Total variance	Intra-community correlation
Latent variable for deprivation	19.51	1.69	1.77	0.16	21.28	0.92
DHS wealth index	0.82	0.12	0.19	0.05	1.01	0.81
Indigenous	17.8	1.54	1.77	1.16	19.57	0.91
Male education	6.59	0.55	1.24	0.12	7.83	0.84
Regions	18.64	1.61	1.77	0.16	20.41	0.91
Distance to the closest municipal capital	14.09	1.23	1.78	0.16	15.87	0.89
Risk of drought	18.76	1.63	1.78	0.16	23.64	0.95
All	5.12	0.43	1.25	0.12	7.61	0.89

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

Table 4.5: Estimates of the effect of the determinants on the community-level score of the latent variable for household deprivation; univariate and multivariate models

		Univariate models		Multivariate model	
Model	**Variable**	**Coeff.**	**95% CI**	**Coeff.**	**95% CI**
Indigenous	Indigenous	-2.67	[-3.25; -2.09]	-1.47	[-1.84; -1.10]
	(LR test - vs empty model)	X^2 =86.23 (d.f.=1)			
Male education	Community-level mean years of male education	1.08	[0.99; 1.17]	0.92	[0.84; 1.01]
	Group mean centred years of male education	0.19	[0.17; 0.20]	0.19	[0.17; 0.20]
	(LR test - vs empty model)	X^2 =1720.81 (d.f.=2)			
Regions [ref. La Paz]	Chuquisaca	-0.66	[-1.76; -0.43]		
	Cochabamba	0.48	[-0.49; 1.45]		
	Oruro	-0.70	[-1.77; 0.37]		
	Potosí	-1.44	[-2.49; -0.40]		
	Tarija	0.53	[-0.56; 1.62]		
	Santa Cruz	0.76	[-0.15; 1.68]		
	Beni	-2.40	[-3.77; -1.13]		
	Pando	0.94	[-0.72; 2.60]		
	(LR test - vs empty model)	X^2 =40.31 (d.f.=8)			
Distance to the closest municipal capital	Distance	-0.19	[-0.21; -0.16]	-0.07	[-0.08; -0.05]
	(LR test - vs empty model)	X^2 =269.15 (d.f.=1)			
Risk of drought [ref. High]	Very low	2.14	[-0.46; 4.73]	0.30	[-1.16; 1.70]
	Low	4.92	[2.33; 7.52]	2.03	[0.60; 3.47]
	Medium	3.89	[1.36; 6.43]	1.53	[0.14; 2.92]
	(LR test - vs empty model)	X^2 =43.50 (d.f.=3)			

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

4.7.2) Univariate models

SEM allowed the investigation of the factors associated with deprivation segregation, by including community-level covariates in the model. Table 4.4 reports the estimates of the between- and within-community variance components of the latent variable for household deprivation, while Table 4.5 shows the results of the univariate and multivariate models of Equations (4.2) and (4.3).

Firstly, the inclusion of the variable *Indigenous* did not substantially change the values of the between- and within-community variance components in comparison to the empty multilevel model (Table 4.4). The coefficient of *Indigenous* was significantly negative (Table 4.5): communities with a majority indigenous population were more likely to have higher mean deprivation.

Secondly, while including the variable for community-mean male education, the group mean centred household-level education was also included in the model, in order to separate the between- and within-community effects, as explained earlier (Equation (4.3)). A drop in the total variance was observed (Table 4.4). This was due to a large decrease in the between-community variance component (from 18.69 in the empty multilevel model to 6.69): the inclusion of the contextual variable for the mean community level of education explained 64.2% of the between-community variance. The within-community variance component fell from 1.72 to 1.20 due to the inclusion of the group mean centred household-level education, leading to an intra-community correlation of 0.85, slightly lower than the empty multilevel model. Both coefficients related to male education were significant and positive (Table 4.5). The between effect indicated that the higher the mean level of male education within a community, the lower the mean level of deprivation in that community. The within effect indicated that the higher the proportion of educated men in a community, the lower the likelihood of their households being deprived. A sensitivity analysis including maternal instead of paternal education was carried out. The results of this model, shown in the Appendix in Section 4.10, indicate no substantial differences in comparison to the model including male education.

Thirdly, the inclusion of the variable *Region* did not substantially modify the between-community and within-community variance in comparison to the empty multilevel model (Table 4.4). Two regions, Potosí and Beni, had a significantly higher level of deprivation than La Paz (Table 4.5).

As a fourth result, little impact on the within-community variance component was observed after the inclusion of the variable *Distance to municipal capital*, while a substantial drop of almost one-third was observed for the between-community component (from 23.41 in the empty multilevel model to 16.18, Table 4.4). The coefficient was significantly positive: every additional kilometre of distance from the closest municipal capital was associated with an average decrease of 0.18 in the community-level score of the latent variable for household deprivation (Table 4.5).

Finally, no substantial drop in the between-community and within-community variance components was observed when including the variable *Risk of drought*, compared to the empty multilevel model (Table 4.4). The coefficients shown in Table 4.5 indicate that the communities located in the medium- and low-risk areas of drought had a lower mean level of deprivation than the communities in areas of high risk.

4.7.3) Multivariate model

Four variables were included in the multivariate model. *Region* was not included in the model, since it was highly correlated with *Risk of drought*: the areas of risk overlapped with many of the Bolivian regions. For instance, the whole area at high risk of drought was included in the regions of Oruro and Potosí. Therefore, *Risk of drought* was preferred because of its higher theoretical value as a potential explanation for the segregation of deprivation within communities, being a cause of selective rural-urban migration (Balderrama, 2011).

The between-community component was equal to 5.19, and it showed a further drop when compared to the univariate model including *Male education* (Table 4.4). The within-community variance, equal to 1.21, was almost constant in the model that included *Male education.* This led to an estimated intra-community correlation of 0.89: roughly 90% of the between-community variance was explained by the four contextual variables included in the model. All of the coefficients were significant in the multivariate model, except for the variable referring to very low risk of drought (Table 4.5). Little difference was found in the interpretation when compared to the univariate models: rural, indigenous communities with a lower mean level of male education and at higher risk of drought were significantly more likely to have a higher mean deprivation.

The model including all of the covariates was preferred to all of the univariate models considered earlier (i.e. $X^2 = 1659.79$, d.f.=6 if compared to the model including the distance to the closest municipal capital, and $X^2 = 208.13$, d.f.=5 if compared to the model including the variables for male education).

Given the random error introduced in the DHS GIS datasets, a sensitivity analysis using the binary variable for urban or rural place of living provided in the DHS dataset instead of the distance to the closest municipal capital was carried out (results in the Appendix in Section 4.11). Another sensitivity analysis changing the categorisation of these communities to the area at risk of drought that they might have been misplaced from was carried out in the Appendix in Section 4.12. No substantial differences in comparison to the model including the continuous variable were observed.

4.8) Discussion

The main result from the empty multilevel model is that households within the same community had extremely similar scores on the latent variable of deprivation, resulting in a high level of segregation. This finding is consistent with previous studies: Castellanos (2007) highlighted that indigenous households in rural Bolivian communities had a relatively low level of inequality. The main source of variation in deprivation in Bolivia is therefore due to differences across communities. The same conclusion is obtained when calculating the dissimilarity index, since half of the deprived households would have to move to different communities in order to reproduce a distribution matching that of the whole country, indicating a considerable level of segregation. Moreover, alternative models using the DHS wealth index instead of the latent variable were fitted. The DHS wealth index, built with PCA, led to an underestimation of the proportion of variation in wealth explained by the grouping of households within communities. This difference was due to the fact that the DHS wealth index did not take into account the measurement error, as well as the different selection of observed items in the construction of the two indices after the investigation of the correlation matrix in Section 4.6.1.

A second results if that communities with a majority indigenous population were found to be more likely to have higher mean deprivation. Indigenous origins are associated with poverty in rural Bolivian communities (Albo 1994; Grootaert and Narayan 2004); the Bolivian indigenous population is mainly clustered in the *Altiplano* and *Valle* regions in isolated rural communities, with high vulnerability to natural hazards and a subsequent lack of roads, access to markets, and social infrastructure (Buzaglo and Calzadilla 2009). At least until 2008, the indigenous population suffered from social exclusion, and were characterised by higher levels of poverty and illiteracy in comparison to the non-indigenous population (Castellanos, 2007). Despite recent political advances, the indigenous population remained economically marginalised, and their poverty gap with the white and mestizo populations increased between 1997 and 2002 (Gigler, 2009). Therefore, due to their disadvantaged position, the concentration of indigenous households in certain areas leads to the segregation of deprivation. Moreover, Zoomers (2006) highlighted the fact that heterogeneity exists not only between indigenous and non-indigenous communities, but also between neighbouring indigenous villages. In rural communities that depend on agricultural activity, differences in the mean level of deprivation across communities might arise from differing access to irrigation water and roads (ibid). In communities that do not depend mainly on farming, patterns of migration can impact the level of deprivation

(Punch, 2004). Heterogeneity across indigenous and non-indigenous communities could also be due to differences in inheritance patterns and gender relations (Zoomers, 2006).

When interpreting the models including community-level education, it was found that the higher the mean level of male education within a community, the lower the mean level of deprivation in that community. Education underlies a broad range of socioeconomic factors, including lower economic conditions (Wight et al. 2006), that lead to deprivation segregation. However, this relationship could have variations within the Bolivian territory. For instance, Punch (2004) pointed out that education might have a minor role in predicting the socioeconomic status of young people in Bolivia's rural areas close to the Argentinian border, where migration can have a bigger impact on occupational status, and consequently on the level of deprivation within the community. Education is also strongly related to ethnicity, since a high proportion of indigenous people have no formal education (Castellanos, 2007). Bolivian indigenous people are also found to have a lower return from education in terms of earning compared to the non-indigenous population (Psacharopoulos, 1993). However, the multivariate model in this analysis found education to be associated with the segregation of deprivation while also taking into account ethnicity.

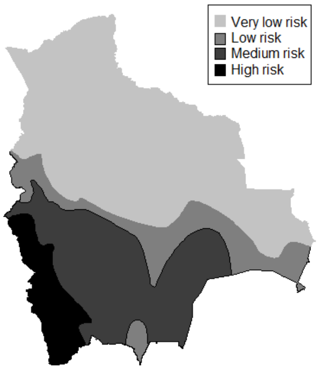
A fourth result is that two regions, Potosí and Beni, had a significantly higher level of deprivation than La Paz. The territory of Potosí, located in the South-West of the country, is mainly mountainous, posing issues of accessibility, as well as difficulties in promoting extensive agricultural exploitation. This region presents the highest presence of indigenous population (Castellanos 2007), and has been affected several times by severe drought (Gray-Molina et al. 2002). Beni's case is different: this region is rich in raw materials and represents one of the biggest agricultural centres in Bolivia (Vadez et al. 2004). Despite its richness in natural resources, the level of poverty is still high, as it is a mainly rural territory, which lacks big urban centres and is in a logistically marginal area when compared to the leading Bolivian economic poles (Weisbrot and Sandoval 2008). Figure 4.1 maps Potosí and Beni in Bolivia.

Figure 4.1: Bolivian regions with a significantly higher level of deprivation than La Paz

A fifth result is that the higher the distance of a community from the closest municipal capital, the higher the likelihood of that community to be deprived. This result is consistent with Rutstein's (2008) findings based on the 2003 Bolivian DHS dataset; when comparing the means of urban and rural areas, the urban communities were found to be wealthier than the rural populations. Rural populations are strongly dependent on farming productivity, which leads to a high vulnerability to shocks such as drought or flooding (Castellanos, 2007). Access to the market for agricultural goods might also be limited by geographical isolation and a lack of roads, leading to a strong dependency on intermediaries that, in the presence of asymmetrical information, can affect peasants' income (Buzaglo and Calzadilla, 2009). Rural areas are likely to face a lack of infrastructure and basic services, like health and educational facilities, electricity and piped water (Andersen, 2002). Due to the distribution of Bolivia's rural population over extended mountainous and forested areas, issues of geographical accessibility contribute to the high cost of the extension of basic services to the totality of the population (ibid). Rural populations are also exposed to endemic diseases that can affect labour productivity and consequently levels of deprivation (Buzaglo and Calzadilla 2009), since 26.7% of rural households retrieve water from a source that is considered unsafe, and 56.7% lack basic sanitation services (against, respectively, 5.4 and 9.3% in urban areas) (Coa and Ochoa 2008).

Finally, communities located in the medium- and low-risk areas of drought had a lower mean level of deprivation than the communities in areas of high risk (Figure 4.2).

Figure 4.2: Risk of drought in Bolivia



Prolonged droughts have affected the South-West part of Bolivia, causing soil erosion and reducing the presence of vegetation (Kessler and Stroosnijder, 2006). These phenomena have had a great impact on rural populations, which rely heavily on farming and livestock, and are the main cause of the drop in agricultural productivity observed over the last decades in Bolivia (Benton, 1993). Farming has therefore progressively become a risky activity (Zoomers, 2006). Climate change has triggered rural-urban migration; a rapid process of urbanisation was observed in Bolivia between the 1980s and the 2000s (World Bank 2015). Punch (2004) observed that in a rural Bolivian village in Tarija (located in the area at medium risk of drought) migration rather than education is considered the best way to improve living standards, since migrant work offers more security and immediate benefits. Rural-urban migration is associated with the uneven residential sorting of migrants within the urban environment, increasing the level of urban residential segregation. Moreover, the only non-significant difference in the mean levels of deprivation was observed between the low-risk and high-risk areas. This can be partially explained by analysing the rural-urban migration flows. Balderrama's (2011) study on migration from the rural Northern Potosí area identified four main destination areas: Cochabamba (for construction work), Llallagua (for mining, construction work, trade and education), Huanuni (for mining), and Santa Cruz (for construction work). None of these destinations are located in the areas at very low risk of drought; the first three are in the medium risk territory, while Santa Cruz is at low risk. Therefore, selective migration might be the reason for the significant difference in the community means of deprivation between low- and medium-risk communities and communities belonging to high-risk areas.

To sum up, ethnicity, education, administrative region, distance to urban centres and risk of drought were found to be significant predictors of deprivation segregation in Bolivia.

4.9) Conclusion

This study proposed a new general SEM approach to the study of geographical segregation, by extending the multilevel modelling approach proposed by Goldstein and Noden (2003) to handle constructs measured by multiple indicators. This approach enabled us to not just quantify the extent of segregation but to model patterns of segregation as function of contextual factors.

The proposed multilevel SEM approach was applied in a study of deprivation segregation in Bolivia, a country that presented among the highest indicators of poverty and deprivation in Latin America (Coa and Ochoa 2009). By analysing the 2008 DHS data, a latent variable for household deprivation was created from a set of six observed items, and simultaneously included in the SEM models, addressing issues related to measurement error (Muthén, 1997). Bolivia was found to have a high level of segregation of deprivation, since a high proportion of variation in the latent variable was due to the grouping of households within communities. This result was consistent with the calculation of the dissimilarity index for this sample, which was equal to 0.51. Ethnicity, education, administrative region, distance to urban centres and drought-induced migration significantly explained the differences in the mean level of deprivation across Bolivian villages. This analysis highlighted the differences in the use of the latent variable in comparison to the DHS wealth index; the inclusion of this latter measure led to an underestimation of the magnitude of the segregation of deprivation in Bolivia, since the DHS wealth index did not take into account measurement error and the items used in the construction of the two indices were slightly different.

The results of the analysis have implications for social and health policies. By identifying the contextual factors associated with the segregation of deprivation, this study provides evidence of the mechanisms that lead to economic and social segregation. This analysis helps in identifying the segregation of deprivation within Bolivia and highlights crucial sectors to be developed in order to reduce the spatial unevenness in the distribution of wealth, linked to social exclusion, diminished opportunities for human capital development and lower access to public services. Reducing inequality across Bolivian communities could also positively affect health indicators, since contexts of concentrated deprivation are associated with higher mortality and higher exposure to infectious diseases (Fiscella and Franks 1997; Szwarcwald et al. 2002). The findings regarding the magnitude of deprivation segregation in Bolivia are also of interest when considering the association between deprivation and neonatal and post-neonatal mortality. The analysis in Chapter 5, which assesses mean community-level deprivation and variation in deprivation within communities as predictors of neonatal and post-neonatal mortality, takes into account the fact that those findings are specific to a context with a low degree of variation in deprivation within communities, and may not be generalised to more unequal contexts.

4.10) Appendix: Models including maternal instead of paternal education

In the model including *Female education*, the between-PSU variance and intra-PSU correlation are slightly lower than those in the model including *Male education* (Table 4.6). The coefficients of both between and within effects are very similar to those referring to *Male education* (Table 4.7).

Table 4.6: Variance decomposition of the latent variable for household deprivation; model including PSU-level mean female education instead of PSU-level mean male education

	Between-PSU variance	**SE**	**Within-PSU variance**	**SE**	**Total variance**	**Intra-PSU correlation**
Female education	5.64	0.47	1.16	0.11	6.80	0.83

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

Table 4.7: Estimates of the effect of the determinants on the community-level score of the latent variable for household deprivation; univariate model including PSU-level mean female education instead of PSU-level mean male education

	Coeff.	**95% CIs**
PSU-level mean years of female education	1.05	[0.97; 1.14]
Group mean centred years of female education	0.18	[0.17; 0.20]

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

4.11) Appendix: Models including the binary variable *Urban* instead of the distance to the closest municipal capital

In the model including *Urban*, the intra-PSU correlation is lower than those of the model including *Distance to municipal capital* (Table 4.8), but the coefficients of all of the covariates included in the multivariate model are very similar to those in the model including *Distance to municipal capital*: urban PSUs present a significantly lower mean deprivation (Table 4.9).

Table 4.8: Variance decomposition of the latent variable for household deprivation; model including Urban instead of Distance to municipal capital

	Between-PSU variance	**SE**	**Within-PSU variance**	**SE**	**Total variance**	**Intra-PSU correlation**
Female education	3.44	0.29	1.26	0.12	4.70	0.73

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

Table 4.9: Estimates of the effect of the determinants on the community-level score of the latent variable for household deprivation; multivariate model including Urban instead of Distance to municipal capital

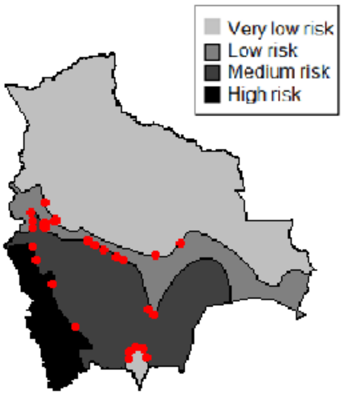
Model	**Variable**	**Coeff.**	**95% CI**
Indigenous	Indigenous	-1.09	[-1.41; -0.78]
Male education	PSU-level mean years of male education	0.59	[0.52; 0.66]
	Group mean centred years of male education	0.19	[0.17; 0.20]
Rurality [ref. Rural]	Urban	3.83	[3.41; 4.26]
Risk of drought [ref. High]	Very low	-0.54	[-1.74; 0.65]
	Low	1.30	[0.11; 2.50]
	Medium	0.60	[-0.55; 1.76]

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

4.12) Appendix: Models changing categorisation of *Risk of drought* for communities within 5 kilometres of the border between different areas

Figure 4.3 shows the position of the 46 communities that lie within 5 kilometres of the borders between areas at different risk of drought.

Figure 4.3: Communities within 5km of the border between areas at different risk of drought



Tables 4.10 and 4.11 present the result from the multivariate model in which the categorisation of these communities has been modified to the adjacent area of risk of drought. The intra-community correlation is very similar to that of the original model, and no substantial difference is observed in the magnitude and significance of the coefficients of any of the covariates included in the multivariate model.

Table 4.10: Variance decomposition of the latent variable for household deprivation; model changing categorisation of Risk of drought for communities within 5km of the border between different areas

	Between-community variance	**SE**	**Within-community variance**	**SE**	**Total variance**	**Intra-community correlation**
All (including modified *Risk of drought*)	5.12	0.42	1.25	0.12	6.37	0.80

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

Table 4.11: Estimates of the effect of the determinants on the community-level score of the latent variable for household deprivation; multivariate model changing categorisation of Risk of drought for communities within 5km of the border between different areas

Model	**Variable**	**Coeff.**	**95% CI**
Indigenous	Indigenous	-1.47	[-1.84; -1.10]
Male education	Community-level mean years of male education	0.92	[0.84; 1.01]
	Group mean centred years of male education	0.19	[0.17; 0.20]
Distance to the closest municipal capital	Distance	-0.07	[-0.08; -0.05]
Risk of drought (modified) [ref. High]	Very low	0.90	[-0.32; 2.12]
	Low	2.48	[1.26; 3.70]
	Medium	2.13	[0.96; 3.31]

Source: Demographic and Health Surveys. Sample size: 19,564 households, 999 communities

5. How does deprivation affect neonatal and post-neonatal mortality? Patterns of socioeconomic determinants of neonatal and post-neonatal mortality in Bolivia

5.1) Introduction

In many studies on neonatal and infant mortality, traditional biodemographic determinants only account for a limited proportion of household-level variation in mortality (Bengtsson and Dribe, 2010; Edvinsson and Janssens, 2012). While many studies have focused on the socioeconomic determinants of infant and child mortality, the neonatal and post-neonatal determinants require further investigation (Neal, 2009). The determinant of primary interest in this analysis is deprivation, interpreted as a lack of basic needs related to housing conditions and living standards.

Chapter 3 analysed the macro-level patterns of association between housing conditions and mortality occurring in the neonatal and post-neonatal periods, with countries as the units of analysis. As observed earlier, a macro-level approach in the analysis of socioeconomic determinants of mortality has some drawbacks: the use of aggregated measures can lead to ecological fallacy, that is a biased estimate of the individual-level associations between the macro-level determinants and health outcomes. The micro-level analysis carried out in this chapter addresses this issue. Moreover, micro-level analyses allow for studying the association between individual-level mortality and determinants measured at higher levels (household and community level).

As seen in Chapter 2, the literature suggests that deprivation might affect mortality through three mechanisms, leading to the absolute-deprivation, relative-deprivation and deprivation-inequality hypotheses (Johannesson, 2004). The absolute-deprivation hypothesis states that the absolute manifestation of deprivation is a determinant of mortality. This hypothesis has found broad support in explaining post-neonatal mortality (Bruce et al., 2000), while the picture is unclear for neonatal mortality (Bobak and Leon, 1992; Rahman et al., 2010). The relative-deprivation hypothesis considers the level of deprivation relative to the average level of the group of reference as a determinant of mortality, through social comparisons that generate stress and corrosion in terms of social cohesion, which can lead to negative health outcomes (Wilkinson, 1997). There is some evidence of an association between unfavourable social comparisons and negative infant health outcomes, but previous studies have been conducted in high-income countries (Reagan et al., 2007; Lhila and Simon, 2010; Olson et al., 2010; Tacke and Waldmann, 2013). Finally, the deprivation-inequality hypothesis considers the contextual effect of the variation in deprivation within communities as a determinant of mortality, for which inequality can be a hazard for the whole population, not only for the households with less favourable social comparisons. So far, most of the literature on deprivation inequality and relative deprivation and health has focused on adults (Balsa et al., 2010). This analysis simultaneously assesses the significance of each of the mechanisms linking deprivation to the components of infant mortality, both in the neonatal and post-neonatal periods. This chapter focuses on the determinants of neonatal and post-neonatal mortality in Bolivia in 2008. In that year, Bolivia had among the highest neonatal and post-neonatal mortality rates in the continent (Coa and Ochoa 2009). Marked inequality in neonatal and post-neonatal mortality indicators existed across the country, with a strong urban/rural gap (Pooley et al. 2008) and a higher incidence of mortality among indigenous newborns (Castellanos 2007). Furthermore, in 2008 we can assess the first results of the Bolivian health reform, which started in 1996 and was further developed in 2002. Bolivia also experienced widespread poverty (Coa and Ochoa 2009) and had one of the highest levels of economic inequality in Latin America (World Bank 2014).

The research questions that this analysis aims to answer are “How important are absolute deprivation, relative deprivation and deprivation inequality in determining neonatal and post-neonatal mortality at the micro level, for the case of Bolivia?” and “Does the size of the area for which relative deprivation and deprivation inequality are calculated affect their association with neonatal and post-neonatal mortality?”.

A structural equation model (SEM) approach, combining a three-level discrete-time event history model for mortality with a latent variable model for deprivation measured at the household level, is applied to data from the 2008 Bolivian Demographic and Health Survey (DHS). Separate models are fitted to estimate the effects of the covariates of interest on mortality occurring in the neonatal and the post-neonatal periods. SEM allows the simultaneous creation of a latent variable for household deprivation, its decomposition into between-community and within-community between-household components, and their inclusion in the model as predictors of mortality. As specified in Chapter 4, the latent variable for household deprivation is measured by a set of observed binary items related to housing environment and living conditions. Their inclusion is guided by the theoretical framework for the determinants of neonatal and post-neonatal mortality specified in Chapter 2. Alternative models with municipalities instead of communities as higher-level units in the multilevel structure were also fitted. Municipalities are larger than communities, and might therefore better reflect the extent of social class differences in a society (Wilkinson and Pickett, 2006). The last section of this chapter shows the results of the models including both socioeconomic and proximal determinants of neonatal and post-neonatal mortality identified in the theoretical framework in Chapter 2.

5.2) Hypotheses linking deprivation and infant mortality

As described in Sections 2.3 and 4.2.1, in this thesis household deprivation is conceptualised as a lack of basic needs related to living standards and housing conditions. This unidimensional and non-monetary definition of deprivation allows for studying the net effect of housing conditions and living standards on neonatal and post-neonatal mortality, while accounting for the effect of the other dimensions of poverty. As highlighted in Section 1.1, gaps in the literature exist in relation to the association between deprivation and neonatal mortality, especially in low- and middle-income countries (Lhila and Simon, 2010; Kayode et al., 2014).

The link between the three manifestations of deprivation and neonatal and post-neonatal health outcomes is discussed in detail in Chapter 2. These manifestations led to three hypotheses linking deprivation and neonatal and post-neonatal mortality, which are tested in this study. The absolute-deprivation hypothesis states that the absolute level of deprivation is an important determinant of child health. The relative-deprivation hypothesis states that it is more the relative level of deprivation rather than its absolute level that influences infant mortality. Finally, the deprivation-inequality hypothesis states that inequality in the distribution of deprivation within communities is the major determinant of infant mortality. An important feature of this chapter is that relative deprivation and deprivation inequality were measured both within communities and within larger areas like municipalities, and the results were compared (in Section 5.6.5), since the relationship between inequality and mortality might depend on the size of the area for which inequality was calculated (Wilkinson and Pickett, 2006), and a community might be too small an area to reflect the extent of the social class differences. While Turley (2002) considered that comparisons over large areas such as states are implausible, in particular among children, Wilkinson and Pickett (2006) argued that “the lower class identity of people in a poor neighbourhood is inevitably defined in relation to a hierarchy which includes a knowledge of the existence of superior classes who may live in other areas some distance away”. For instance, using the Ecuadorian Living Standards Measurement Survey, Larrea and Kawachi (2005) found a significant association between child malnutrition and economic inequality calculated at the provincial scale, but not at the municipal or local level.

5.3) The Bolivian context

5.3.1) Trends of neonatal and post-neonatal mortality in Bolivia

In 2008 – at the time of the DHS survey – Bolivia was one of the most delayed countries in the demographic transition in Latin America, although there were signs of improving trends in each mortality-related indicator (Coa and Ochoa, 2009). The Bolivian neonatal and infant mortality rates were among the highest on the continent, at respectively 24 and 40 deaths per 1,000 live births (Word Bank, 2014). Figure 5.1 shows that, despite a steady decline in neonatal and infant mortality rates, Bolivia was still far from the average of its neighbouring countries in 2008 (own elaboration on World Bank (2014) data). The gap between it and the rest of the Latin American countries was still evident, as shown in Figure 5.2 (World Health Organization, 2017). There was also a sharp decrease in maternal mortality, from 399 deaths per 100,000 live births in 1994 to 310 in 2008 (Ochoa et al., 1994; Coa and Ochoa, 2009).

Figure 5.1: Neonatal and infant mortality rates for Bolivia and its neighbouring countries

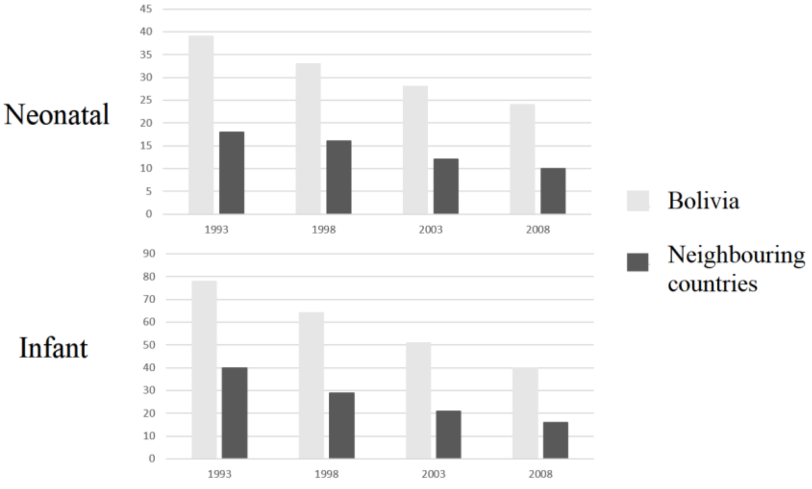


Figure 5.2: Infant mortality rates, Americas 2010

There was marked urban/rural inequality for all of the demographic indicators. In 2008, the neonatal mortality rates were estimated to be equal to 23 deaths per 1,000 live births in urban areas, versus 40 in rural areas, while the post-neonatal mortality rates were, respectively, 20 and 35 deaths per 1,000 live births. There were several potential reasons for this disparity, among which the inadequate coverage of health services in rural areas played an important role. Rural areas were the poorest and most geographically segregated and had a greater presence of indigenous people (Castellanos, 2007). Moreover, the percentage of the population using improved sanitation in 2011 was estimated to be 57 in urban areas, against only 24 in rural regions (Population Reference, 2013).

5.3.2) The Bolivian health reform

The Bolivian health system has undergone major changes in recent decades. In 1996 the Bolivian government began a health reform that provided a health insurance policy and a set of interventions targeting maternal and children health (Pooley et al., 2008). The health reform was further developed twice, in 1998 and 2002, extending the number of interventions as well as the target population (ibid). In particular, in the 2002 development, the target population was extended to all mothers and children under-five, and the goal was to supply a set of free services in order to remove the economic barriers limiting access to high-quality health services, with the aim of reducing maternal and child mortality (Ledo and Soria, 2011). The 2002 development of the health reform also included two extensions that aimed to broaden the coverage of health services, Extensa and Community Pharmacy. Extensa aimed to reach remote areas of Bolivia by means of the “Brigades”, which were composed of multidisciplinary mobile health staff, each covering between 40 and 50 communities, who were visited every second month (Pooley, 2008). On the other hand, the Community Pharmacy service’s objective was to provide basic drugs to remote rural communities located far away from health facilities (Pooley, 2008). Moreover, the implementation of the Intercultural Health Scheme programme in 2002 was an important step making traditional medicine and modern biomedical healthcare interact and be complementary. It allowed for overcoming psychological and physical barriers to access to health services, due to their inadequate coverage, especially in rural areas (Perry and Gesler, 2000), and to cultural beliefs that led to a mistrust of formal medicine (Kitts, 1996).

Since the implementation of the Bolivian health reform, deliveries with skilled birth attendants have increased, and there has been substantial growth in the use of prenatal care and inpatient births covered by insurance (Koblinsky, 2003). The Bolivian indicators concerning prenatal and childbirth care, malnutrition and infant and maternal mortality show a steady increase since the health programme began (Coa and Ochoa, 2009), which is also due to household attendance, the promotion of positive practices concerning health and education, and easy access and feasible transportation to health facilities. However, some areas in which the health reform still showed inadequate results in 2008 were related to the urban/rural gap, the quality of services and the creation of standardised performance indicators. In particular, inequalities in the coverage of skilled birth attendant deliveries existed, with a considerable proportion of the rural indigenous and poor population still not being reached by the programme (Pooley, 2008).

5.4) Data and measures

5.4.1) The 2008 Bolivian Demographic and Health Survey

The 2008 Bolivian DHS is the data source for this micro-level analysis (Coa and Ochoa, 2009). Implemented by the Bolivian National Institute of Statistics, the survey was conducted between February and June 2008. DHS datasets have a three-level structure, with children nested within households, nested within primary sample units. As in Chapter 4 and in previous studies (Uthman et al. 2011; Robson et al. 2012), primary sample units were considered as proxies of communities, defined as clusters of households within a geographical living environment. Primary sample units were the only area identifier available in the DHS survey, and were used as higher-level units in our models. Municipalities, obtained by linking the DHS dataset to an external Global Information System (GIS) dataset (GeoBolivia, 2016), were also used as higher-level units instead of communities in other multilevel models.

Only births occurring within 10 years of the survey were included in the analysis, in order to minimise changes in the values of time-varying covariates and in mortality patterns over time, and to minimise recall error (Eisenhower et al., 1991). Models that include births occurring within 5 years of the survey were also fitted, and no substantial changes in the results were observed (results in the Appendix in Section 5.10). Surviving children born within a year of the date of the interview and therefore having incomplete exposure to the risk of post-neonatal mortality, were excluded from the analysis in order to avoid issues related to different lengths of exposure. The analyses considered only children in households with complete data on the ownership of the items related to housing conditions and predictors of mortality, giving a total of 17,478 children belonging to 5,849 households and to 988 communities. Table 5.1 describes the distribution by wealth quintile for the complete record dataset and for the set of records excluded for the above-mentioned reasons. The exclusions have little impact on the distribution of the DHS wealth index in the sample.

Table 5.1: Records excluded from the analysis by quintile of the DHS wealth index, row percentages

	Poorest	Poorer	Middle	Richer	Richest	Total number of children
Complete record dataset	28.8	22.2	20.3	16.6	12.2	17,478
Excluded: born before 1998	25.9	21.9	19.3	17.8	15.1	20,840
Excluded: born within one year from the interview	24.8	25.4	21.4	17.9	10.5	201
Excluded: incomplete record	28.4	17.9	19.4	17.3	17.0	1,836

5.4.2) Mortality outcome

Separate models were fitted for the neonatal and post-neonatal periods. The dependent variable of the structural model for mortality was based on the child's age at death, or, for surviving children (with censored durations), on the age at the end of the observation period. For neonatal mortality, a binary response indicated whether the child died within the first 28 days of life. The post-neonatal period was divided into three 112-day sub-periods, and a set of up to three binary responses indicates whether the child died within each of those periods. For instance, for a child who died within the first sub-interval of the post-neonatal period (between the 29th and 140th days of life), the response vector is [1]; a child dying in the first interval then leaves the risk set, and there are no responses for the subsequent intervals. For a child who died within the third sub-interval of the post-neonatal period (between the 252nd and 365th days of life), the vector is $[0\ 0\ 1]^T$, while for a child who survives until the first birthday the vector is $[0\ 0\ 0]^T$.

There were 983 deaths within the first year of life in the sample, corresponding to 5.6% of the sample (standard deviation equal to 0.25), 527 of which happened within the neonatal period. The number of neonatal deaths per community ranges from 0 to 9, while the number of post-neonatal deaths per community ranges from 0 to 6.

5.4.3) Other socioeconomic determinants

A set of seven socioeconomic determinants was included in the models as control variables: paternal occupation, maternal highest education level, whether the community is mainly indigenous, distance to the closest municipal capital, administrative region, whether the delivery took place before or after the implementation of the Bolivian health reform, and whether the distance to health facilities was a problem or not. These socioeconomic determinants were the variables included in the theoretical framework for the determinants of neonatal and post-neonatal mortality specified in Chapter 2. All of the variables were provided by DHS, apart from the distance to the closest municipal capital, which was obtained by linking the GIS location of the centroid of the DHS clusters with other GIS datasets, as specified in Chapter 4. This variable was considered to be a better approximation of the “urban-rural continuum” (Woods, 2003) than the binary variable provided by the DHS. Table 5.2 provides the list and codes of the socioeconomic determinants.

Table 5.2: List of socioeconomic covariates

Variables	**Data summaries**
Socioeconomic determinant	
Paternal occupation	
Not working or absent	3.3% (n=576)
Blue-collar	63.2% (n=11,046)
White- or pink-collar	33.5% (n=5,855)
Maternal education (years)	Mean 6.9 (sd=4.8)
Indigenous village	
Indigenous	62.7% (n=10,959)
Non-indigenous	37.3% (n=6,519)
Distance to the closest municipal capital (km)	Mean 10.7 (sd=13.0)
Administrative region	
Beni	7.2% (n=1,258)
Chuquisaca	9.4% (n=1,659)
Cochabamba	13.7% (n=2,394)
La Paz	18.3% (n=3,198)
Oruro	8.5% (n=1,485)
Pando	4.3% (n=768)
Potosí	12.5% (n=2,190)
Santa Cruz	17.9% (n=3,128)
Tarija	8.0% (n=1,398)
Distance to health facilities	
Not a big problem	43.7% (n=7,638)
Big problem	56.3% (n=9,840)
Pre/post Bolivian health reform	
Before 2002	41.8% (n=7,306)
After 2002	58.2% (n=10,172)
Binary items measuring deprivation	
Electricity	0.76% (n=13,217)
Water	0.84% (n=14,725)
Sanitation	0.70% (n=12,196)
Floor	0.66% (n=11,467)
Cooking fuel	0.61% (n=10,687)
Refrigerator	0.27% (n=4,771)

Paternal rather than maternal occupation was chosen in this analysis, since paternal income is a strong determinant of the socioeconomic status of a household (Cornia, 2014; Thomas, 1990). In Bolivian indigenous societies, men are more likely to assume the position of the breadwinner within the family (Paulson et al., 1996), while women are often dedicated to domestic tasks and children's education (Molyneux and Thomson, 2011). Paternal occupation was categorised with the categories "Not working or absent", "Blue-collar" (including agricultural employees, skilled and unskilled manual workers), and “White- or pink-collar” (including teachers, managers, clericals, and workers in service sector). The categories “Not working” and “Absent” were merged due to the small number of fathers not working (0.87% of the sample). However, it could be argued that maternal occupation can explain child health outcomes, especially in single parent households. Therefore, a sensitivity analysis using maternal instead of paternal education was carried out (results in the Appendix in Section 5.11).

As in Chapter 4, the community-level variable for indigenousness indicated communities with a majority of indigenous or non-indigenous villages. However, Bolivia presents a variety of indigenous populations (more than thirty according to the 2009 Constitution), and differentials in some demographic behaviours are reported across indigenous groups. For instance, Quechua and Aymara natives have different stillbirth rates in rural areas in Puno (Gonzales, 2007), and differences in the knowledge of the menstrual cycle and in the proportion of unwanted pregnancies have been observed (Alfonso, 2008). Another sensitivity analysis was carried out, specifying whether the indigenous group is Aymara, Quechua, Guarani or other (data provided by DHS). The results are shown in the Appendix in Section 5.12.

The dummy variable indicating whether the birth took place before or after the implementation of the development of the health reform in 2002 was included in the models. However, it is possible that the health system reform reduced the impact of deprivation on mortality by smoothing disparities levels in the access to the health system among different households. Therefore, models including the interactions between the dummy variable for pre/post 2002 and the three socioeconomic determinants of interest were fitted in the Appendix in Section 5.13.

Finally, in relation to the distance to health facilities, the DHS provides a binary variable, with categories “Big problem” and “Not a big problem”, for women’s reported difficulty in getting medical help. A more informative variable would have been the real distance to health facilities, but some issues affected the calculation of such a variable, since no reliable GIS dataset about minor streets and trails was available. It is reasonable to expect that Bolivian women willing to travel to the closest health facility might have to cover longer distances than the straight-line distance between their village and the target. This might be true especially in the mountainous territories, where altitude might make some areas inaccessible (Andersen, 2002). The only available dataset was related to main roads (GeoBolivia, 2013), but this was not sufficiently detailed to include all of the walking trails that women might use. Moreover, the only available GIS dataset related to health facilities referred to 2012 (GeoBolivia, 2012), while the DHS dataset was from 2008. It is reasonable to think that in those four years new hospitals and facilities were built, especially if we consider that after 2008 Bolivia experienced the fastest economic growth in Latin America (Fuentes, 2015). Therefore, the binary DHS variable related to distance to health facilities was preferred to any variable that could have been calculated by means of GIS data.

5.4.4) Municipalities instead of communities as level-three units

Since it has been argued in the literature that the relationship between the distribution of deprivation and health outcomes might depend on the size of the area for which inequality and relative deprivation were calculated (Wilkinson and Pickett, 2006), Section 5.6.5 presents the results of the models in which municipalities rather than communities were used to define the hierarchical structure of the data. The DHS dataset was linked to an external GIS dataset containing information on the borders of Bolivian municipalities (GeoBolivia, 2016). If the centroid of the primary sample unit fell within a municipality, all of the households in that community were assigned to that municipality. Each municipality contained one or more communities. Overall, 243 of the 339 Bolivian municipalities were represented in the DHS sample. The number of communities (988 in total) per municipality ranged from 1 to 68, with a mean of 4. Communities had a mean of 36.5 children, with a standard deviation of 17.9, while municipalities had a mean of 147.4 children, with a standard deviation of 264.9: municipalities contained on average more than four times the number of children of communities.

5.4.5) Proximal determinants

In the 2008 Bolivian DHS dataset, data for many proximal variables were collected only for the most recent birth. After controlling for birth order, data could be considered as missing completely at random, with a two-level structure with children/households nested within communities. The sample size of observations with complete records was 4,602, nested within 951 communities. Table 5.3 provides a list and the values of the proximal variables identified in the theoretical framework for the determinants of neonatal and post-neonatal mortality presented in Chapter 2.

Table 5.3: List of proximal determinants

Newborn's biodemographic factors	
Sex	
Female	48.0% (n=2,208)
Male	52.0% (n=2,394)
Birth weight* (hg)	Mean 33.5 (sd=5.8)
Birth order	Mean 2.9 (sd=2.2)
Preceding birth interval	
First birth	30.8% (n=1,416)
<24 months	15.1% (n=693)
24+ months	54.1% (n=2,493)
Maternal biodemographic factors	
Age at birth	Mean 27.0 (sd=6.8)
Maternal BMI	Quartiles
Delivery factors	
Place of delivery*	
Respondent's home or other home	10.2% (n=470)
Government, private or NGO hospital or health centre	89.8% (n=4,132)
Assistance during birth*	
None or unskilled	5.9% (n=271)
Doctor or nurse	92.1% (n=4,239)
Traditional	2.9% (n=92)
Household practices and choices	
Antenatal care visits*	Mean 5.9 (sd=2.8)
Maternal tetanus injections	
0 injections	23.9% (n=1,098)
1 injection	29.2% (n=1,346)
2+ injections	46.9% (n=2,158)
Breastfeeding* (months)	Mean 9.6 (sd=3.6)

* collected only for the most recent birth

Following Singh et al.'s (2012) categorisation, the variable for maternal tetanus injections was coded with the categories "No injection", "1 injection" and "2+ injections". The variable for place of delivery was dichotomised, with the categories "Respondent's home or other home" and "Government, private or NGO hospital or health centre". The BMI distribution of Bolivian women was different from that in high-income countries, probably due to the low average height (151 centimetres). For this reason, the traditional thresholds of 18.5, 25 and 30 kg/m^2 (World Health Organization, 2006) were not used, but rather quartiles of the distribution of BMI in the sample were considered. Given the U-shaped relationship between a mother's age at birth and neonatal mortality (Conley and Strully, 2012), both the linear and the quadratic transformations of maternal age were included in the model. In relation to birth spacing, the variable for preceding birth interval was categorised as “First birth”, “<24 months”, and “24+ months”.

Problems of endogeneity arise with the variables related to ANC visits, place of delivery and birth weight. The sources of endogeneity in empirical studies are typically simultaneity, measurement error or omitted variables (Wooldridge, 2010); in this case the endogeneity was due to omitted variable bias. In general, when independent variables associated with both the outcome and other predictors are left out of a model, the estimates of the effect of the other predictors are biased (Clarke, 2005).

5.5) Statistical methods

5.5.1) Latent variable model for household deprivation

A latent variable for household deprivation was constructed from a set of six observed items (electricity, water, sanitation, material of the floor, cooking fuel, and refrigerator), which were chosen after the investigation of the correlation matrix, as explained in Chapter 4. A latent variable approach allows for addressing issues related to measurement error that would arise when using the DHS wealth index.

5.5.2) Multilevel structural equation model

In this analysis, the structural model included latent variables for household and community deprivation as predictors in a multilevel logistic model for mortality. The SEM involved a single-level measurement model for household deprivation, and a three-level model for mortality, with children nested within households nested within communities (or municipalities). By combining a multilevel generalised linear model for a binary outcome with a single-level latent trait model (Bartholomew et al., 2011), this SEM can be included in Skrondal and Rabe-Hesketh’s (2004) framework of ‘generalised linear latent and mixed models’ (GLLAMM).

This study also involved the decomposition of the latent variable into between- and within-community components, since the latent variable for household deprivation might include some unmeasured characteristics of the community, such as availability of utilities at the community level, or area-specific investments. The effects of both components on mortality were of interest. The between-community effect represented the influence of community-level deprivation on mortality, while the within-community effect allowed for assessing the relative-deprivation hypothesis, as explained later in Section 5.5.6. Such decomposition is common in multilevel models (Curran and Bauer, 2011; Steele et al., 2016).

The analyses were carried out using the MPlus software (Muthén and Muthén, 2010). Bayesian estimation was the only method available for three-level SEMs in MPlus (ibid). Monte Carlo Markov chain (MCMC) methods provided an approximation of the posterior distributions of the parameters. The results of this analysis were based on two parallel chains. The length of the chains depended on the convergence criterion, since convergence was reached when the proportional scale reduction factor was close enough to 1 for each parameter (Gelman et al., 2004). The maximum number of iterations was fixed at 50,000. The first half of each chain was discarded as burn-in. Default non-informative priors were used: $N(0, \infty)$ for intercepts, regression slopes, and parameters of the measurement model, Inverse Gamma $IG(0, -1)$ for variance covariance blocks of size 1, and Inverse Wishart $IW(0, -p - 1)$ for variance covariance blocks, where $p > 1$ was the size of the blocks (Asparouhov and Muthén, 2010). The parameter estimates were computed as the mean of the chain values for each parameter from the MCMC estimation, while the standard errors were the standard deviations of the chain values. The fitted models were compared to the same models with an increased chain length of 100,000 iterations (Appendix in Section 5.14). For the two-level models in Section 5.6.6, maximum likelihood estimation was used.

5.5.3) Measurement model for deprivation

The measurement model specifies the relationship between the latent variable for household deprivation and its manifestations (the observed items). The form of the measurement model in this analysis was the same as in the previous study on deprivation clustering (Chapter 4).

Denote by x_{rjk} the response on the r^{th} $(r = 1, \dots, p)$ binary item for household j $(j = 1, \dots, n_k)$, nested within community k $(k = 1, \dots, K)$. Then the logit of the probability of household j in community k to own item r can be expressed as

$$\text{logit}\big(P(x_{rjk} = 1)\big) = \text{logit}\big(\pi_{rjk}\big) = \alpha_{r1}\eta_{jk} - \alpha_{r0} \qquad (5.1)$$

where $\eta_{jk} \sim N(0, \sigma_\eta^2)$ is the household-level latent variable for deprivation, and α_{r0} and α_{r1} are, respectively, the difficulty and discrimination parameters. The difficulty parameter α_{r0} indicates how "difficult" it is to own an item, while the discrimination parameter α_{r1} indicates how well the r^{th} item discriminates between households with different scores for household deprivation. In order to identify the model, one of the α_{r1}s is constrained to 1. By doing so, the scale of the latent variable and the scale of the chosen item are set to be the same.

5.5.4) Structural model for effects of deprivation on mortality for testing the absolute-deprivation hypothesis

The absolute-deprivation hypothesis states that the absolute level of individual deprivation is an important determinant of neonatal and post-neonatal mortality (Johannesson, 2004). In order to test this hypothesis, the latent variable for household deprivation is included as a predictor of mortality in the structural model.

Denote by d_{ijk} the binary response for neonatal the death of child *i* in household *j* in community *k*, coded 1 for a death and 0 for survival, and let $p_{ijk} = \Pr(d_{ijk} = 1)$. The structural model for the effect of household deprivation on neonatal mortality is

$$\text{logit}(p_{ijk}) = \boldsymbol{\beta}^T \boldsymbol{x}_{ijk} + \lambda \eta_{jk} + v_{jk}^{(hh)} + v_k^{(PSU)} \tag{5.2}$$

where $\boldsymbol{x}_{ijk}$ is a vector of covariates, η_{jk} is the latent variable for household deprivation as in Equation (5.1), $v_{jk}^{(hh)} \sim N(0, \sigma_v^{2(hh)})$ is the household random effect, and $v_k^{(PSU)} \sim N(0, \sigma_v^{2(PSU)})$ is the community-level random effect. The test of the absolute-deprivation hypothesis was the test of $\lambda = 0$.

5.5.5) Decomposition of the latent variable for household deprivation into between- and within-community components

The effect of the latent variable for household deprivation in Equation (5.2) also captures the effects of any community-level component of deprivation. It is therefore desirable to decompose the effect of the latent variable into its within- and between-community components (Steele et al., 2016). As explained earlier, the within-community effect is the effect of the level of a household's deprivation relative to the mean deprivation in the community, and it allows for testing the relative-deprivation hypothesis.

The structural model specifying such a decomposition of η_{jk} is

$$\eta_{jk} = \beta_k + u_{jk}^{(hh)}$$

$$\beta_k = \gamma_{00} + u_k^{(PSU)} \qquad (5.3)$$

where $u_{jk}^{(hh)} \sim N(0, \sigma_u^{2^{(hh)}})$ is the within-community component of household deprivation and $u_k^{(PSU)} \sim N(0, \sigma_u^{2^{(PSU)}})$ is the between-community component of household deprivation. Their variances $\sigma_u^{2^{(hh)}}$ and $\sigma_u^{2^{(PSU)}}$ are the within-community between-household and the between-community variances in deprivation.

In the two-level model for the within-between-community decomposition of the latent variable for household deprivation, the intra-community correlation is ${ICC_u}^{(PSU)} = \sigma_u^{2^{(PSU)}} / (\sigma_u^{2^{(hh)}} + \sigma_u^{2^{(PSU)}})$.

5.5.6) Structural model for mortality with decomposition of the latent variable for deprivation for testing the relative-deprivation hypothesis

The relative-deprivation hypothesis states that the relative level of deprivation is a better predictor of health outcomes than absolute deprivation (Johannesson, 2004). Relative deprivation is defined as a comparison of an individual's deprivation score with the mean level of deprivation in a reference group, in this case other households in the community. By decomposing the latent variable for household deprivation into its between- and within-community components, Equations (5.3) and (5.4) allow for an assessment of the relative-deprivation hypothesis: the within-community component of deprivation represents the difference between the score of the latent variable of each household and the average of their community. According to the relative-deprivation hypothesis, the larger the negative departure of a household score in deprivation from the community mean, the higher the mortality, due to less favourable social comparisons.

The structural model below represents an extension of Equation (5.2), and its equation is

$$\text{logit}(p_{ijk}) = \boldsymbol{\beta}^T \boldsymbol{x}_{ijk} + \lambda_W u_{jk}^{(hh)} + \lambda_B u_k^{(PSU)} + v_{jk}^{(hh)} + v_k^{(PSU)} \tag{5.4}$$

where the within effect λ_W represents the effect of the departure of each household's score in deprivation from their community mean, while the between effect λ_B represents the effect of the between community-level mean of deprivation. The test of the relative-deprivation hypothesis was the test of $\lambda_W = 0$.

5.5.7) Inclusion of the community-level standard deviation of the scores of the latent variable for household deprivation for testing the deprivation-inequality hypothesis

The third hypothesis is the deprivation-inequality hypothesis: the distribution of deprivation within a community has an effect on mortality (Johannesson, 2004). Inequality results from non-random sorting of households into communities, which leads to the concentration of households of similar characteristics within areas. The community-level standard deviation of the scores of the latent variable for household deprivation is used as a measure of inequality within communities.

The use of the standard deviation as a measure of inequality is justified by the fact that the design of the Bolivian DHS survey implied no more than 20 households per community, making the use of the most widespread measures of inequality, such as the Gini coefficient (Dorfman, 1979), Kaplan's measure (Daly et al., 1998), or the Theil index (Weich et al., 2002), inappropriate. For instance, the Gini coefficient would underestimate the extent of inequality with such a small sample size (Ghosh, 1975). Therefore, the within-community standard deviation of the scores of the latent variable for deprivation was chosen as a measure of inequality, since this measure may suffer less than others from small-sample bias and does not require as large a sample as measures based on the quintiles or deciles of the distribution.

When the analysis was carried out, no SEM software allowed simultaneous modelling of a latent variable and the inclusion of its standard deviation in the structural model. For this reason, a two-stage estimation process was used. First, the factor scores of the latent variable for household deprivation were obtained from the measurement model without the within-between decomposition of Equation (5.1), and the within-community standard deviations were calculated from the scores. In the second stage, the standard deviation was included as a predictor in the SEM where the measurement model was estimated simultaneously with the mortality model.

The structural model below represents an extension of Equation (5.4), and its equation is

$$\text{logit}(p_{ijk}) = \boldsymbol{\beta}^T \boldsymbol{x}_{ijk} + \lambda_W u_{jk}^{(hh)} + \lambda_B u_k^{(PSU)} + \lambda_{ineq} \widehat{\text{SD}}_k(\hat{\eta}_{jk}^{(hh)}) + v_{jk}^{(hh)} + v_k^{(PSU)} \qquad (5.5)$$

where $\widehat{\text{SD}}_k(\hat{\eta}_{jk}^{(hh)})$ is the community-level standard deviation of the scores of the latent variable for household deprivation, measuring within-community variation. The test of the deprivation-inequality hypothesis was the test of $\lambda_{ineq} = 0$.

5.5.8) Specification of the model for post-neonatal mortality

For post-neonatal mortality, three binary responses d_{tijk} indicate whether a child died during interval t, $(t = 1,2,3)$. The structural models for post-neonatal mortality therefore have the same form as Equations (5.2) and (5.5), but include two changes. The left-hand side of the models become $\text{logit}(p_{tijk})$, where $p_{tijk} = \Pr(d_{tijk} = 1)$ is the probability of death in each of the sub-periods, while on the right-hand side two dummy variables indicating the second and third sub-periods within the post-neonatal period are included in order to allow the hazard of mortality to change over the three intervals. For all of the models presented below only the equation for neonatal mortality is presented.

Since the latent variables have no natural scale, standardised coefficients $\lambda^* = \sigma_u \lambda$ were calculated. Standardised coefficients can be interpreted as the effect of a one standard deviation change in the latent variable on the log-odds of a child death.

5.5.9) Variance partition coefficients and intraclass correlation coefficients

Variance partition coefficients (VPCs) can be calculated to measure the relative magnitude of the variance components (Leckie, 2015). The total variance in mortality is $\sigma_v^{2^{(child)}} + \sigma_v^{2^{(hh)}} + \sigma_v^{2^{(PSU)}}$. For a logit model, the child-level residual variance is $\sigma_v^{2^{(child)}} = \pi^2/3 \cong 3.29$. This is obtained from a latent variable representation of the logistic regression model, for which the continuous underlying mortality risk has a residual term with a standard logistic distribution (Snijders and Bosker, 2012). Therefore, $VPC^{(child)} = 3.29/(3.29 + \sigma_v^{2^{(hh)}} + \sigma_v^{2^{(PSU)}})$, $VPC^{(hh)} = \sigma_v^{2^{(hh)}}/(3.29 + \sigma_v^{2^{(hh)}} + \sigma_v^{2^{(PSU)}})$, and $VPC^{(PSU)} = \sigma_v^{2^{(PSU)}}/(3.29 + \sigma_v^{2^{(hh)}} + \sigma_v^{2^{(PSU)}})$. $VPC^{(child)}$ can be defined as the proportion of residual variance in children's underlying mortality risk that is due to unobserved child characteristics. $VPC^{(hh)}$ and $VPC^{(PSU)}$ are defined in similar ways.

Intraclass correlation coefficients (ICCs) can be calculated in order to assess the degree of homogeneity within a given cluster. In the three-level model for mortality, the household ICC, which is the correlation between the mortality risks of two siblings, is calculated as $ICC_v{}^{(hh)} = (\sigma_v^{2^{(hh)}} + \sigma_v^{2^{(PSU)}})/(\ 3.29 + \sigma_v^{2^{(hh)}} + \sigma_v^{2^{(PSU)}})$.

5.5.10) Controlling for socioeconomic and proximal determinants

For both the neonatal and post-neonatal periods five models were fitted. In Models (a), (b) and (c), the covariates of interest were, respectively, the latent variable for household deprivation defined at the household level, seen in Equation (5.2), the latent variable for household deprivation decomposed into its between- and within-community components, as in Equations (5.3) and (5.4), and the community-level standard deviation of the scores of the latent variable, in Equation (5.5). These models did not include any control variables. Model (d) included the decomposed latent variable and the community-level standard deviation and controlled for the other socioeconomic determinants considered in the theoretical framework, allowing the assessment of the hypotheses linking deprivation and infant mortality. Model (e) included the same socioeconomic control variables as Model (d), but had municipalities instead of communities as higher-level units in the multilevel model. Finally, Model (f) built on Model (d), also including the proximal determinants of neonatal mortality. Table 5.4 summarises the covariates included in each model.

Table 5.4: Order of covariate inclusion

	Model (a)	Model (b)	Model (c)	Model (d)	Model (e)	Model (f)
Latent variable for household deprivation - no decomposition	X					
Latent variable for household deprivation - decomposed into between- and within-community components		X		X		X
Community-level standard deviation of the scores of the latent variable			X	X		X
Latent variable for household deprivation - decomposed into between- and within-municipality components					X	
Municipality-level standard deviation of the scores of the latent variable					X	
Other socioeconomic determinants				X	X	X
Proximal determinants						X

5.5.11) Endogeneity of antenatal care visits, place of delivery, attendance at birth, and birth weight

When including proximal variables, endogeneity arising from omitted variable bias might affect the estimates of the association between endogenous variables (antenatal care (ANC) visits, place of delivery, attendance at birth, and birth weight) and the mortality outcome. Omitted variable bias might arise, for instance, from unobserved factors that affect both a mother’s use of ANC and her child’s mortality risk, leading to a correlation between ANC and the residual in the mortality model. The omitted factors might be related both to complications in pregnancy, like maternal or foetal and placental problems, or to characteristics of the area of residence, such as accessibility or quality of health services. Place of delivery and attendance at birth might be influenced by some unobserved factors, like availability and quality of health services, which were also associated with the outcome variable. Omitted variable bias might also arise in the association between birth weight and mortality risk, since these variables might be influenced by maternal nutrition and complications during gestation and pregnancy.

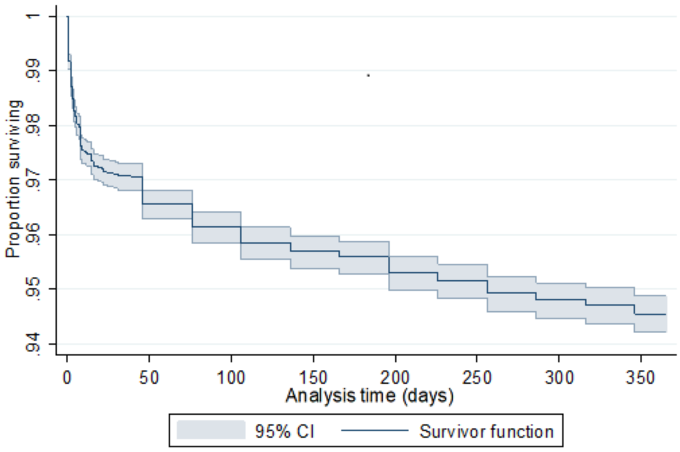
If these variables and the mortality risk were endogenous, single-equation models including each of them as a predictor would produce biased parameter estimates, combining their effect and all of the other unobserved factors linked to mortality, but attributing the net effect the variable alone. The effect of the endogenous variables would therefore be under- or over-estimated, depending on the direction of the effect of the omitted factors on the outcome and the direction of their association with the endogenous variables. Unfortunately, no variables were found to meet the criteria for being a valid instrument for the endogenous variables. For these reasons, the potential problem of endogeneity was not addressed in this analysis. When interpreting the results, we therefore have to acknowledge the fact that the effects of the above-mentioned variables on mortality risk might be biased.

5.6) Results

5.6.1) Life table for neonatal and post-neonatal mortality

The sample size at the beginning of the observation period was 17,478. The total number of infant deaths was 983, of which 527 occurred within the neonatal period, and 456 within the post-neonatal period. In the post-neonatal period, 1,510 observations were lost due to the fact that children with incomplete exposure were not considered. The estimates of the survivor function were therefore 0.97 in the neonatal period and 0.95 in the post-neonatal period. Figure 5.3 shows the Kaplan-Meier survival estimates. There was a steep decline in the survivor function in the first 30 days of life, followed by an almost constant decrease in the following 11 months.

Figure 5.3: Kaplan-Meier estimate of the survival function for the first year of life

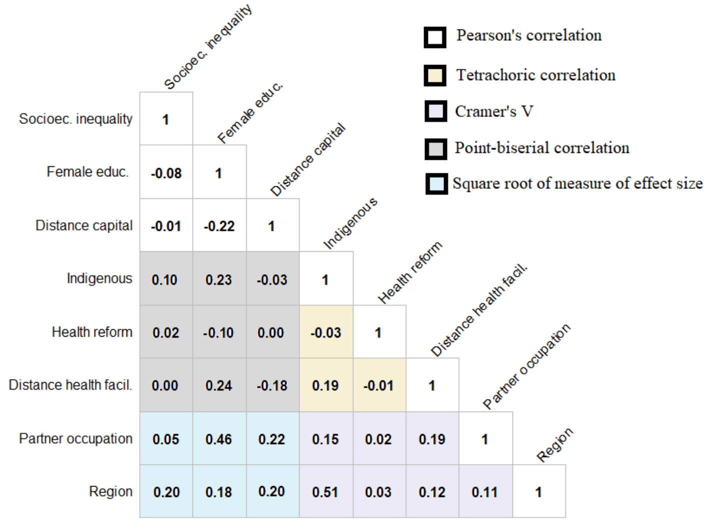


Source: Demographic and Health Surveys. Sample size: 17,478 children

5.6.2) Investigation of the association among the covariates

All of the covariates were weakly correlated, so no issue of multicollinearity arose when including them in the SEM. Table 5.5 shows the measures of the association between each pair of covariates. Person's correlation coefficient was used for pairs of continuous variables (within-community standard deviation of the scores of the latent variable, maternal education and distance to the closest municipal capital), tetrachoric correlation coefficient for binary variables (indigenous village, pre/post Bolivian health reform and distance to health facilities), and Cramer's V for nominal variables (paternal occupation and administrative regions) and for the association between binary and nominal variables. The square root of the measure of effect size in ANOVA can be interpreted as an analogue of the correlation between a continuous and a nominal variable, while the point-biserial correlation coefficient was calculated between continuous and binary variables. The strongest association was found between the variables Region and Indigenous, with a Cramer's V of 0.51.

Table 5.5: Matrix for the association among the covariates



	Socioec. inequality	Female educ.	Distance capital	Indigenous	Health reform	Distance health facil.	Partner occupation	Region
Socioec. inequality	1							
Female educ.	-0.08	1						
Distance capital	-0.01	-0.22	1					
Indigenous	0.10	0.23	-0.03	1				
Health reform	0.02	-0.10	0.00	-0.03	1			
Distance health facil.	0.00	0.24	-0.18	0.19	-0.01	1		
Partner occupation	0.05	0.46	0.22	0.15	0.02	0.19	1	
Region	0.20	0.18	0.20	0.51	0.03	0.12	0.11	1

☐ Pearson's correlation
🟨 Tetrachoric correlation
🟪 Cramer's V
▨ Point-biserial correlation
🟦 Square root of measure of effect size

Source: Demographic and Health Surveys. Sample size: 5,849 households

5.6.3) Measurement model for deprivation

The measurement models related to the neonatal and post-neonatal periods (Table 5.6) presented very similar discrimination and difficulty parameters. This result was expected since the sample in the post-neonatal period corresponded to the sample in the neonatal period, except for the children that experienced neonatal death and those born less than a year from the date of the interview. Refrigerator, floor, and electricity were the items that best discriminated between households with different scores for deprivation, since they had the highest values of the discrimination parameter α_{r1}.

Table 5.6: Discrimination and difficulty parameters, Model (a) for neonatal and post-neonatal periods

	Neonatal period				Post-neonatal period			
Item	**Discr. (α_{r1})**	**SE**	**Diff. (α_{r0})**	**SE**	**Discr. (α_{r1})**	**SE**	**Diff. (α_{r0})**	**SE**
Electricity	1.00	(constrained)	1.59	0.05	1.00	(constrained)	1.60	0.05
Water	0.74	0.05	2.50	0.05	0.72	0.05	2.56	0.05
Sanitation	0.82	0.05	1.34	0.04	0.80	0.05	1.36	0.04
Floor	1.06	0.07	1.00	0.04	1.06	0.07	1.01	0.05
Cooking fuel	0.83	0.05	1.05	0.04	0.82	0.05	1.05	0.04
Refrigerator	1.52	0.09	-0.62	0.05	1.49	0.10	-0.64	0.05

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

Table 5.7: Variance decomposition of the mortality outcome and of the latent variable for household deprivation, all models

	Model (a)				Model (b)				Model (c)				Model (d)			
	Neonatal period		Post-neonatal period		Neonatal period		Post-neonatal period		Neonatal period		Post-neonatal period		Neonatal period		Post-neonatal period	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
Within-community variance of the mortality outcome $(\sigma_v^{2(hh)})$	0.23	0.07	0.10	0.05	0.22	0.05	0.05	0.03	0.17	0.04	0.05	0.02	0.23	0.06	0.07	0.02
Between-community variance of the mortality outcome $(\sigma_v^{2(PSU)})$	0.08	0.02	0.04	0.02	0.07	0.02	0.03	0.02	0.09	0.03	0.04	0.02	0.04	0.02	0.02	0.01
Within-community variance of the l.v. $(\sigma_u^{2(hh)})$	0.77	0.06	0.88	0.08	1.27	0.11	1.27	0.15					1.31	0.11	1.27	0.11
Between-community variance of the l.v. $(\sigma_u^{2(PSU)})$					7.79	0.69	7.78	0.96					8.11	0.76	7.86	0.77
$VPC^{(child)}$	0.91		0.96		0.92		0.98		0.93		0.97		0.92		0.97	
$VPC^{(hh)}$	0.06		0.03		0.06		0.01		0.05		0.01		0.06		0.02	
$VPC^{(PSU)}$	0.02		0.01		0.02		0.01		0.03		0.01		0.01		0.01	
$ICC_v{}^{(hh)}$	0.09		0.04		0.08		0.02		0.07		0.03		0.08		0.03	
$ICC_u{}^{(PSU)}$					0.86		0.86						0.86		0.86	

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

Table 5.7 shows the results of the variance partitioning of Equations (5.3) and (5.4). Given the definition of VPCs provided earlier, it can be said that between 91 and 93% of the variation in neonatal deaths and between 96 and 98% of the variation in post-neonatal mortality risk lay within households between children, between 5 and 6% of the variation in neonatal deaths and between 1 and 3% of the variation in post-neonatal deaths lay within communities between households, and between 2 and 3% of the variation in neonatal deaths and 1% of the variation in post-neonatal deaths lay between communities. In all of the models, the great majority of the variance in both neonatal and post-neonatal mortality lay within households.

The proportion of variation in mortality explained by the grouping of households within communities ranges from 20 to 25% in the models for neonatal mortality, and from 6 to 11% in the models for post-neonatal mortality. Finally, the proportion of variation in the latent variable for household deprivation explained by the grouping of households within communities is around 86%.

5.6.4) Models for neonatal and post-neonatal periods using communities as level-three units

Before analysing the results, it is worth noting that, in order to simplify the interpretation, the sign of the coefficients associated with the latent variable for household deprivation was reversed; in this way, higher scores were associated with higher deprivation.

Tables 5.8 and 5.9 show estimates of the standardised coefficients λ^*, λ_W^* and λ_B^*. In Models (a), the coefficients λ^* of absolute deprivation were positive and significant for both periods: for a one standard deviation increase in household deprivation, we expected a 15% increase in the odds of death within the neonatal period and a 17% increase within the post-neonatal period (both p-values<0.01). In the models without control variables, absolute deprivation was associated with neonatal and post-neonatal mortality, with a slightly stronger association with post-neonatal mortality than with neonatal mortality. The same pattern was found after controlling for socioeconomic determinants (λ^*=0.07 in the neonatal period, λ^*=0.08 in the post-neonatal period; full results not shown).

Table 5.8 shows the results for Models (b). The coefficients λ_B^* of the community-level mean deprivation were positive and significant (p-values<0.001) for both models: the higher the community-level deprivation, the higher the odds of a child born in that community to experience neonatal and post-neonatal death. The only significant coefficient λ_W^* of relative deprivation was that for the post-neonatal period (p-value=0.02). It had a positive value: a one standard deviation increase in the difference between a household score of the latent variable for deprivation and the community mean score was associated with a 6% increase in the odds of post-neonatal death. The coefficient λ_W^* of relative deprivation in the neonatal period was not significant (p-value=0.14).

In Models (c) (Table 5.8), the coefficients λ_{ineq} of deprivation inequality in the post-neonatal period had a borderline p-value of 0.06. Its negative coefficient indicated that higher deprivation inequality within a community is associated with a decrease in the odds of post-neonatal death. The coefficient λ_{ineq} in the neonatal period was not significant (p-value=0.45): deprivation inequality was not a significant predictor of neonatal mortality.

Table 5.8: Estimates of the effect of deprivation on log-odds of a child death and 95% C.I.s; Models (a), (b) and (c) for neonatal and post-neonatal periods

			Neonatal period		Post-neonatal period	
	Determinant	Parameter	Mean	95% CI	Mean	95% CI
Model (a)	Absolute deprivation	λ^*	**0.14**	**[0.09; 0.20]**	**0.16**	**[0.11; 0.22]**
	Length of the chain		2,300		6,100	
Model (b)	Relative deprivation	λ_W^*	0.04	[-0.03; 0.11]	**0.06**	**[0.00; 0.12]**
	Community-level mean deprivation	λ_B^*	**0.15**	**[0.10; 0.20]**	**0.13**	**[0.09; 0.18]**
	Length of the chain		9,400		10,300	
Model (c)	Deprivation inequality	λ_{ineq}	-0.02	[-0.47; 0.27]	-0.19	[-0.41; 0.05]
	Length of the chain		2,000		5,900	

Note: coefficients for the intercept and for the two sub-periods within the post-neonatal period not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero.

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

The results from Model (a) showed that higher household-level absolute deprivation was associated with a higher risk of both neonatal and post-neonatal mortality. However, the latent variable for household deprivation might capture some unmeasured community-level characteristics: a decomposition into between-community and within-community between-household effects allowed the role of the two components of deprivation to be disentangled (Curran and Bauer, 2011; Steele et al., 2016). The results for Models (d), which involved the within-between-community decomposition of deprivation and included the set of socioeconomic determinants identified in the theoretical framework, are shown in Table 5.9.

Table 5.9: Estimates of the effect of the socioeconomic determinants on log-odds of a child death and 95% C.I.s; Model (d) for neonatal and post-neonatal periods

Model (d)		Neonatal period		Post-neonatal period	
Determinant	Parameter	Mean	95% CI	Mean	95% CI
Relative deprivation	λ_W^*	-0.01	[-0.07; 0.06]	0.02	[-0.03; 0.08]
Community-level mean deprivation	λ_B^*	**0.09**	**[0.03; 0.17]**	0.05	[-0.01; 0.11]
Deprivation inequality	λ_{ineq}	0.12	[-0.19; 0.39]	-0.06	[-0.30; 0.20]
Paternal occupation [ref. Not working or absent]	Blue-collar	**-0.17**	**[-0.30; -0.03]**	-0.10	[-0.19; 0.03]
	White- or pink-collar	**-0.17**	**[-0.31; -0.03]**	-0.15	[-0.25; 0.00]
Maternal education	Years of education	**-0.02**	**[-0.04; -0.01]**	**-0.02**	**[-0.03; -0.02]**
Indigenous [ref. Not indigenous]	Indigenous	**0.10**	**[0.00; 0.19]**	0.03	[-0.06; 0.12]
Distance to the closest municipal capital	Distance	-0.30	[-0.80; 0.20]	0.00	[-0.30; 0.40]
Regions [ref. La Paz]	Chuquisaca	**-0.18**	**[-0.37; -0.00]**	**-0.25**	**[-0.42; -0.06]**
	Cochabamba	-0.05	[-0.21; 0.10]	-0.02	[-0.15; 0.11]
	Oruro	-0.18	[-0.39; 0.01]	0.10	[-0.06; 0.25]
	Potosí	0.11	[-0.05; 0.26]	**0.14**	**[0.02; 0.25]**
	Tarija	-0.18	[-0.41; 0.03]	**-0.23**	**[-0.41; -0.03]**
	Santa Cruz	**-0.31**	**[-0.47; -0.13]**	**-0.16**	**[-0.32; -0.03]**
	Beni	**-0.30**	**[-0.52; -0.10]**	**-0.23**	**[-0.43; -0.01]**
	Pando	-0.21	[-0.51; 0.08]	0.06	[-0.19; 0.28]
Bolivian health reform (2002) [ref. Before]	After 2002	**-0.14**	**[-0.22; -0.06]**	-0.05	[-0.12; 0.02]
Distance to health facilities [ref. Not a big problem]	Big problem	0.03	[-0.06; 0.13]	0.07	[-0.03; 0.15]
Time interval within post-neonatal period	Sub-period 2			**-0.40**	**[-0.49; -0.32]**
	Sub-period 3			**-0.35**	**[-0.44; -0.27]**
Length of the chains		4,700		6,700	

Note: coefficients for the intercepts are not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero.

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

The coefficients λ_B^* associated with the community mean level of deprivation $u_k^{(PSU)}$ were both significant (p-value<0.01 in the neonatal period and p-value=0.04 in the post-neonatal period): a one standard deviation increase in community-level deprivation was associated with a 9% increase in the odds of neonatal death, and with a 5% increase in the odds of post-neonatal death. After accounting for the effects of socioeconomic confounding variables, the coefficient λ_W^* of relative deprivation calculated at the community level was no longer significant in the post-neonatal period (p-value=0.23). Also, λ_W^* in the neonatal period was not significant (p-value=0.44). Neither of the coefficients λ_{ineq} of deprivation inequality were significant (p-value=0.24 in the neonatal period and p-value=0.34 in the post-neonatal period).

The Appendix in Section 5.10 presents the results of the models including births occurring within 5 years before the survey. Models including maternal rather than paternal occupation were also fitted (Appendix in Section 5.11). The coefficients in these Appendices were very similar to those in Table 5.9. The Appendix in Section 5.12 shows the results of the models including the specification of the indigenous groups to which households belong; since no significant differences were found in neonatal and post-neonatal mortality between Aymara, Quechua and other indigenous groups, the binary variable for indigenous or non-indigenous was kept in the models. The Appendix in Section 5.13 shows the results of the models including the interaction between the three variable of interest and the binary variable for pre/post 2002. As in the previous models, community-level deprivation was the only significant socioeconomic determinant in both periods, while none of the interaction terms was significant in the post-neonatal period. The Appendix in Section 5.14 shows the results of Models (d) after increasing the number of MCMC iterations to 100,000; the results were very similar to those in Table 5.9. Finally, models including the DHS wealth index instead of the latent variable for household deprivation were fitted, and the results are shown in the Appendix in Section 5.15. Many differences in the significance of the coefficients could be found, among which the main difference was related to the lower significance of the effect of community-level deprivation on post-neonatal mortality.

5.6.5) Models for neonatal and post-neonatal periods using municipalities as level-three units

Since the size of the area for which relative inequality and deprivation inequality were calculated might affect the significance of their association with neonatal and post-neonatal mortality outcomes (Wilkinson and Pickett, 2006), Model (e) was run using municipalities instead of communities as level-three units. Relative deprivation was therefore calculated as the within-municipality component of deprivation after decomposing the latent variable for household deprivation into its between- and within-municipality components. Deprivation inequality was calculated as the within-municipality standard deviation of the scores of the latent variable for household deprivation. The other control variables were calculated as before, except for distance to the closest municipal capital, which was kept as a household-level variable.

Table 5.10: Variance decomposition of the mortality outcome and of the latent variable for household deprivation, Model (e) for neonatal and post-neonatal mortality using municipalities as level-three units

	Neonatal period		Post-neonatal period	
	Est.	SE	Est.	SE
Within-municipality variance of the mortality outcome ($\sigma_v^{2(hh)}$)	0.27	0.05	0.10	0.03
Between-municipality variance of the mortality outcome ($\sigma_v^{2(MUN)}$)	0.01	0.01	0.01	0.01
Within-municipality variance of the l.v. ($\sigma_{u_W}^{2\ (hh)}$)	2.75	0.24	2.65	0.22
Between-municipality variance of the l.v. ($\sigma_{u_B}^{2\ (MUN)}$)	3.78	0.52	3.61	0.49
$ICC_v{}^{(hh)}$	0.08		0.03	
$ICC_u{}^{(MUN)}$	0.57		0.58	

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 243 municipalities

Table 5.10 shows the results of the variance partitioning. In particular, there was a considerable amount of within-municipality variation in deprivation, which ensured that household- and municipal-level deprivation were not indistinguishable before and after the decomposition, and therefore allowed the effects of the variables for relative deprivation and municipal-level mean deprivation to be disentangled.

For the neonatal period, the results were similar to those using communities as level-three units. The mean level of deprivation calculated at the municipal level was the only significant variable of interest, and relative deprivation and deprivation inequality had no association with the mortality outcome (Table 5.11). In contrast to models with communities as higher-level units, relative deprivation had a significant association with post-neonatal mortality. A one standard deviation increase in the difference between a household’s score for the latent variable for deprivation and the municipal-level mean score was associated with a 7% increase in the odds of post-neonatal death.

Table 5.11: Estimates of the effect of the socioeconomic determinants on log-odds of a child death and 95% C.I.s; Model (e) for neonatal and post-neonatal periods including socioeconomic variables using municipalities as level-three units

Model (e)		Neonatal period		Post-neonatal period	
Determinant	Parameter	Mean	95% CI	Mean	95% CI
Relative deprivation	λ_W^*	0.01	[-0.06; 0.07]	0.07	[0.01; 0.13]
Municipal-level mean deprivation	λ_B^*	0.09	[0.02; 0.15]	0.04	[-0.02; 0.09]
Deprivation inequality	λ_{ineq}	0.05	[-0.19; 0.26]	-0.03	[-0.23; 0.18]
Paternal occupation [ref. Not working or absent]	Blue-collar	-0.12	[-0.27; 0.03]	0.01	[-0.13; 0.12]
	White- or pink-collar	-0.12	[-0.28; 0.04]	-0.07	[-0.21; 0.06]
Maternal education	Years of education	-0.02	[-0.03; -0.01]	-0.02	[-0.03; -0.01]
Indigenous [ref. Not indigenous]	Indigenous	-0.02	[-0.26; 0.21]	-0.02	[-0.23; 0.19]
Distance to the closest municipal capital	Distance	-0.10	[-0.60; 0.30]	-0.03	[-0.23; 0.18]
Regions [ref. La Paz]	Chuquisaca	-0.26	[-0.50; -0.06]	-0.24	[-0.45; -0.05]
	Cochabamba	-0.04	[-0.22; 0.12]	0.00	[-0.16; 0.15]
	Oruro	-0.25	[-0.46; -0.04]	0.13	[-0.05; 0.30]
	Potosí	0.08	[-0.09; 0.24]	0.15	[-0.01; 0.31]
	Tarija	-0.30	[-0.63; 0.01]	-0.24	[-0.53; 0.05]
	Santa Cruz	-0.42	[-0.68; -0.17]	-0.20	[-0.43; 0.01]
	Beni	-0.36	[-0.68; -0.03]	-0.33	[-0.65; -0.04]
	Pando	-0.23	[-0.65; 0.15]	-0.01	[-0.38; 0.33]
Bolivian health reform (2002) [ref. Before]	After 2002	-0.13	[-0.22; -0.06]	-0.05	[-0.12; 0.02]
Distance to health facilities [ref. Not a big problem]	Big problem	0.06	[-0.04; 0.16]	0.07	[-0.01; 0.17]
Time interval within post-neonatal period	Sub-period 2			-0.39	[-0.48; -0.30]
	Sub-period 3			-0.35	[-0.45; -0.26]

Note: coefficients for the intercepts are not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero.

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 243 municipalities

5.6.6) Models for neonatal and post-neonatal periods including proximal variables

Table 5.12 shows the results of the two-level model for mortality risk. In comparison to Model (d), the binary variable indicating whether the birth took place before or after the Bolivian health reform was excluded, since in this dataset all of the births took place after 2002 (many biodemographic variables were collected only for the most recent birth). The variable for presence of a younger sibling was not included either, because none of the children included in the dataset had a sibling born within 12 months of their birth. The variables place of delivery and assistance at birth were highly associated, with a Cramer's V equal to 0.91. The variable assistance at birth was therefore excluded from the model. Finally, breastfeeding was included only for the post-neonatal period, since its duration was measured in months, and by construction all of the neonatal deaths had a record of zero months of breastfeeding.

None of the covariates of interest were significantly associated with the mortality outcomes. Neither of the standardised coefficients λ_B^* of community-level mean deprivation (p-value=0.72 in the neonatal period and p-value=0.21 in the post-neonatal period), or the standardised coefficient λ_W^* of relative deprivation (p-values=0.82 in both periods) were significant. Also λ_{ineq}, the coefficients of deprivation inequality, were not significantly associated with either outcome (p-value=0.83 in the neonatal period and p-value=0.85 in the post-neonatal period). However, the fact that the coefficients λ_W^*, λ_B^* and λ_{ineq} were no longer significant might be due to the fact that the sample changed in comparison to Models (d) rather than the inclusion of the proximal variables, since these coefficients were also not significant in the two-level model including only the socioeconomic variables applied to the reduced dataset (for λ_W^*, p-values=0.73 in the neonatal period and 0.76 in the post-neonatal period; for λ_B^*, p-values=0.99 in both periods; and for λ_{ineq}, p-values=0.86 and 0.97, full results not shown).

Table 5.12: Estimates of the effect of socioeconomic and proximal determinants on log-odds of a child death and 95% C.I.s model; Model (f) for neonatal and post-neonatal periods including proximal determinants

Model (f)		Neonatal period		Post-neonatal period	
Determinant	Variable	Coef.	95% CI	Coef.	95% CI
Relative deprivation	λ_W^*	-0.15	[-0.81; 0.52]	0.05	[-0.99; 1.08]
Community-level mean deprivation	λ_B^*	0.23	[-0.22; 0.69]	0.37	[-0.47; 1.20]
Deprivation inequality	λ_{ineq}	0.25	[-1.81; 2.32]	0.23	[-3.05; 3.51]
Paternal occupation [ref. Not working or absent]	Blue-collar	-0.51	[-1.56; 0.55]	-2.25	[-1.80; 1.10]
	White- or pink-collar	-0.30	[-1.39; 0.78]	-2.38	[-1.93; 0.92]
Maternal education	Years of education	-0.05	[-0.14; 0.04]	-0.06	[-0.19; 0.07]
Indigenous [ref. Not indigenous]	Indigenous	0.37	[-0.57; 1.30]	-1.56	[-2.78; -0.33]
Distance to the closest municipal capital	Distance	0.00	[-0.30; 0.30]	0.02	[-0.02; 0.06]
Regions [ref. La Paz]	Chuquisaca	-1.91	[-4.07; 0.26]	-2.14	[-4.76; 0.48]
	Cochabamba	0.01	[-1.16; 1.18]	-0.71	[-2.24; 0.82]
	Oruro	0.24	[-0.88; 1.35]	-0.87	[-2.66; 0.92]
	Potosí	0.37	[-0.65; 1.39]	-0.97	[-2.53; 0.60]
	Tarija	-0.07	[-1.66; 1.53]	-4.45	[-7.25; -1.65]
	Santa Cruz	-0.14	[-1.42; 1.14]	-3.86	[-5.82; -1.90]
	Beni	-1.44	[-3.66; 0.79]	-4.00	[-6.54; -1.45]
	Pando	-0.24	[-2.46; 1.98]	-3.78	[-6.24; -1.32]
Distance to health facilities [ref. Not a big problem]	Big problem	-0.06	[-0.75; 0.63]	0.51	[-0.41; 1.42]
Antenatal care visits	Antenatal care visits	-0.05	[-0.18; 0.07]	-0.12	[-0.30; 0.05]
Maternal tetanus injection [ref. 0 injection]	1 injection	-0.41	[-1.21; 0.40]	-0.22	[-1.40; 0.96]
	2+ injections	-0.77	[-1.60; 0.07]	0.16	[-0.94; 1.26]
Place of delivery [ref. Respondent's home or other home]	Government, private or NGO hospital or health centre	0.99	[-0.35; 2.33]	0.19	[-1.37; 1.75]
Birth order	Birth order	0.04	[-0.17; 0.25]	0.31	[-0.02; 0.64]
Birth weight	Birth weight	-0.02	[-0.03; -0.02]	-0.01	[-0.01; 0.00]
Sex [ref. Female]	Male	0.80	[0.10; 1.49]	0.54	[-0.39; 1.46]
Breastfeeding	Months of breastfeeding			-0.55	[-0.74; -0.36]
Maternal BMI [ref. First quartile]	Second quartile	0.34	[-0.48; 1.16]	-0.46	[-1.82; 0.91]
	Third quartile	-0.22	[-1.22; 0.79]	0.49	[-0.64; 1.62]
	Fourth quartile	-0.43	[-1.47; 0.62]	-0.31	[-1.58; 0.96]
Age at birth	Age at birth	0.10	[-0.28; 0.48]	-0.27	[-0.76; 0.21]
	Squared age at birth	-0.00	[-0.01; 0.01]	0.00	[-0.01; 0.01]
Preceding birth interval [ref. First birth]	<24 months	0.08	[-1.20; 1.36]	0.54	[-0.99; 2.07]
	24+ months	-0.01	[-1.09; 1.08]	0.85	[-0.54; 2.25]
Time interval within post-neonatal period	Sub-period 2			-0.79	[-1.77; 0.18]
	Sub-period 3			-0.38	[-1.34; 0.57]

Note: coefficients for the intercepts are not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero. Source: Demographic and Health Surveys. Sample size: 4,602 children, 951 communities

5.7) Discussion

5.7.1) Household-level absolute deprivation as a predictor of neonatal and post-neonatal mortality

In Models a), absolute deprivation was found to be associated with both mortality outcomes, with a stronger association with post-neonatal mortality than with neonatal mortality. In the literature, mortality occurring within the first year of life has been found to be strongly associated with the quality of sanitation (Fink et al., 2011), water (Esrey, 1996), and indoor air pollution (Epstein et al., 2013). There is evidence that the association between air pollution and mortality is weaker in the neonatal period than in the post-neonatal period (Bobak and Leon, 1992; Bobak and Leon, 1999). While overall infant mortality is strongly correlated with the quality of sanitation, water and indoor air (Bruce et al., 2000; Esrey, 1996), environmental factors might have a smaller association with neonatal mortality because of the shorter length of exposure of only 28 days and because of the stronger association between neonatal mortality and endogenous factors such as congenital diseases (Taskaya and Demirkiran, 2017).

5.7.2) Community-level absolute deprivation as a predictor of neonatal and post-neonatal mortality

In Models d), the community mean level of deprivation was found to be significantly associated with both mortality outcomes. Several studies have found environmental deprivation to be a risk factor for a set of birth outcomes; in particular, a low neighbourhood socioeconomic level is associated with perinatal mortality (De Graaf et al., 2012), preterm birth (O’Campo et al., 2007), post-neonatal mortality (Guildea et al., 2001), and malformations (Deguen et al., 2016). Many aspects of the mean community-level of deprivation, ranging from housing to safety and social cohesion, might have an effect on birth outcomes. Moreover, especially in low- and middle-income countries, improving environmental factors, like extending the electric grid and enhancing latrine facilities and sources of domestic water, can have a fundamental role in birth outcomes (Patel, 1980; Van de Poel, 2009; Jaadla and Puur, 2016).

This finding can be linked with the results of Chapter 4, which investigated the community-level determinants of clustering of deprivation. Contextual variables related to ethnicity, education, accessibility and drought-induced migration were assessed as determinants of the differences in mean deprivation across communities. Since higher neonatal and post-neonatal mortality was found in contexts of concentrated deprivation, reducing the differences in deprivation among communities might also lead to a reduction in neonatal and post-neonatal mortality. Deprivation clustering can be linked, among other things, to social exclusion and lower access to public services.

5.7.3) Relative deprivation as a predictor of neonatal and post-neonatal mortality

No significant association was found between relative deprivation calculated at the community level and the components of infant mortality in Models d). However, relative deprivation had a significant association with post-neonatal mortality when using municipalities as clusters in Models e). Inequality calculated in broader areas reflects the extent of how hierarchical a society is, and in fact communities might be too small to reveal the degree of social stratification (Wilkinson and Pickett, 2006). Since the main source of variation in deprivation in Bolivia was found, in Chapter 4, to be between communities rather than within them, calculating deprivation inequality and relative deprivation within communities might not reflect deprivation in relation to the wider society (Wilkinson, 1997). As they are on average more than four time larger than communities, municipalities allow for social comparisons with broader sectors of the society, and might therefore be more suitable areas to calculate deprivation inequality and relative deprivation than communities. Municipalities also allow better estimation of the standard deviations of the scores of the latent variable for household deprivation, since communities are often small in size (up to 20 households per community). Calculating inequalities in small areas might exclude comparisons with wealthier communities, and, especially in communities with a high degree of deprivation, social comparisons in poor areas might still be done with members of better-off communities (Bourdieu, 1984; Canadine, 1998). The average quality of housing in Bolivia is low (Castellanos, 2007), and households with a higher level of deprivation in comparison to the mean of their municipality may have a severe lack of material resources (Lynch et al., 2001) such as access to clean water and sanitation, leading to higher post-neonatal mortality. A lack of basic needs was found to have a role in post-neonatal mortality, while neonatal mortality might not be affected due to its stronger relationship with intrauterine factors (Black et al., 2010). Another explanation might refer to the influence on parents, since unfavourable social comparisons can impact on the quality of their relationships and social life (Reagan et al., 2007). However, this pathway is an unlikely explanation in Bolivia, since smoking is uncommon, especially in rural areas, where the prevalence of smokers may be low due to the price of cigarettes and the widespread poverty

(Albalak et al., 1999). In this sample only 6.4% of the women interviewed declared themselves to be smokers.

5.7.4) Deprivation inequality as a predictor of neonatal and post-neonatal mortality

Neither of the coefficients of deprivation inequality were significant in Models d) and e). This finding is consistent with Szwarcwald et al.’s (2002) analysis, which, to my knowledge, is the only study that has analysed the relationship between socioeconomic inequality and neonatal and infant mortality at the micro level. Mayer and Sarin (2005) found income inequality to be a significant predictor of post-neonatal mortality at the macro level. However, at the macro level, the ecological fallacy could lead to an artefactual correlation between inequality and health outcomes (Gravelle, 1998). Due to the curvilinear relationship between health and income, a one-unit increase in income is associated with a higher increase in health among the poor than among the rich. Therefore, any reduction in inequality generated by transfers from the richer to the poorer leads to a better global health outcome. When interpreting the results associated with deprivation inequality, we should take into account that this study was set in a context of widespread deprivation, in which many households lack the resources for an adequate living standard. It has been argued that contextual factors related to the distribution of wealth in a country might have an influence on health only once basic needs are satisfied (Wilkinson, 1994). This might not be the case in Bolivia, where, in 2008, the pragmatic consequences of a poor physical environment were still of primary importance for infant mortality, since children living in poor conditions might be more exposed, among other things, to infections and respiratory problems. Moreover, the conclusions we draw should take into account that the differences across households were small, since we found in Chapter 4 that Bolivian communities have a relatively low level of inequality within communities, and inequality in the country arose mainly from differences across communities. We cannot exclude the possibility that relative deprivation and deprivation inequality measured within communities could be predictors of infant mortality in more unequal contexts.

5.7.5) Models including the proximal determinants

In Models f), including both socioeconomic and proximal control variables, none of the covariates of interest were significantly associated with the mortality outcomes. As discussed in the previous section, the smaller sample size might be the reason for this fact, since these coefficients were also not significant in the two-level model including only the socioeconomic variables applied to the reduced dataset. Moreover, the effect of the socioeconomic distal determinants might be absorbed by the set of mediating proximal factors included in the models (Victora et al., 1997). In the theoretical framework for the determinants of neonatal and post-neonatal mortality described in Section 2.3, a hierarchy among factors was defined, with the set of socioeconomic distal determinants (including deprivation) affecting both the mortality outcome and the set of proximal determinants. It is therefore likely that the effect of absolute deprivation on neonatal and post-neonatal mortality – which was significant in the unadjusted model – was captured here by the set of proximal determinants. It would be inappropriate to state that deprivation had no effect on mortality, since in the model adjusted for proximal determinants its effect was underestimated by the presence of mediating factors.

5.7.6) The effect of the health reform on neonatal and post-neonatal mortality

In Models d), the risk of neonatal mortality was found to be significantly lower for births occurring after 2002, the year in which the third step of the Bolivian health reform was implemented. This finding is consistent with the evaluation of the health reform, which reported that indicators concerning infant mortality have steadily decreased since the health programme began (Coa and Ochoa, 2009). As described in Section 5.3.2, the reform involved making available a set of free services related to prenatal care and delivery with the aim of removing the economic barriers limiting access to high-quality health services (Ledo and Soria, 2011). The Extensa, Community Pharmacy, and Intercultural Health Scheme programmes had the goal of extending the coverage of health services to remote rural areas (Perry and Gesler, 2000), and overcoming the mistrust of modern medicine among the indigenous population (Kitts, 1996). It was reasonable to think that the implementation of the health reform could have reduced the impact of deprivation on mortality, by removing the economic barriers that limit access to high-quality health services among poor households. The models in the Appendix in Section 5.13 tested this hypothesis by including interaction terms between the dummy variable for pre/post 2002 and the three socioeconomic determinants of interest. However, none of the interaction terms was significant in the post-neonatal period, leading to the conclusion that the effect of deprivation on neonatal and post-neonatal mortality was not affected by the implementation of the health reform.

5.7.7) Use of the DHS wealth index instead of the latent variable for household deprivation

The models in the Appendix in Section 5.15 included the DHS wealth index instead of the latent variable for household deprivation, allowing for assessing whether the use of these two indicators led to different results. Many differences in the significance of the coefficients could be found, among which the main difference was related to the lower significance of the effect of community-level deprivation on post-neonatal mortality. As explained in Section 4.4.3, there are several advantages of using a latent variable approach in comparison with the DHS wealth index, mainly related to the fact that the SEM takes into account the measurement error that may bias the estimates of the coefficients, and allows for categorical observed indicators (Muthén, 1997). Moreover, the observed items included in the measurement model for the latent variable were selected based on their correlation coefficient, ensuring that only items related to the latent concept of deprivation were included in the model. The differences observed between the models including the DHS wealth index and the latent variable may therefore be due to the fact that the DHS wealth index did not take into account the measurement error, as well as the different selection of observed items in the construction of the two indicators.

5.8) Limitations

Some limitations exist in relation to the data and methods used in these analyses. When using the 2008 Bolivian DHS, an important limitation is that longitudinal data on deprivation were not available, and we had to assume that deprivation at interview also referred to the 10-year window prior to the survey. Some issues exist regarding the quality of the DHS data referring to neonatal mortality, arising mainly from data heaping at 7 and 28 days (Neal, 2009). The DHS datasets do not include data on stillbirths, which would be of interest when analysing neonatal mortality, since there is evidence of a tendency to misreport neonatal deaths as stillbirths, especially in countries where neonatal mortality rates are an indicator of the quality of health facilities (Aleshina and Redmond, 2005). Moreover, in the 2008 Bolivian DHS dataset, data on proximal variables such as tetanus injections, breastfeeding, antenatal visits, birth weight, place of delivery, and assistance during delivery were collected only for the most recent birth. This led to the two-level model of Section 5.6.6, with child/households nested within communities. Apart from being based on a smaller sample size, the two-level model did not allow us to disentangle birth-specific factors from household-level factors. Data on the timing of initiation of breastfeeding, family practices, and detailed complications were also missing. Some explanatory variables in the micro-level analyses in Chapters 4 and 5 were calculated by linking the position of the centroid of the DHS clusters with external Global Information System (GIS) datasets. Due to issues of confidentiality, the GIS coordinates of each community were randomly displaced, introducing errors of up to 2 kilometres for urban clusters and up to 5 kilometres for rural clusters (Perez-Heydrich et al., 2013). The random displacement of the centroid of the communities could have affected some of the explanatory variables, such as the distance to the closest municipal capital, and the allocation of the clusters into municipalities in Chapter 5. Moreover, as discussed in Section 5.5.11, when including proximal variables, endogeneity arising from omitted variable bias might affect the estimates of the association between four endogenous variables (ANC visits, place of delivery, attendance at birth, and birth weight) and the mortality outcome. Omitted variable bias arises from unobserved factors that affect both the endogenous variables and her child's mortality risk, like maternal problems or characteristics of the area of residence. The results of the analyses must therefore take into account that the correlation between the endogenous variables and the residual in the mortality models can lead to bias in their effect on the mortality risk. It would also have been of interest to run the same model including each of the observed items used in the construction of the latent variable for household deprivation as a predictor. However, given the strong correlation among the observed items (Table 4.2 in Chapter 4), issues of multicollinearity would make it impossible to disentangle the effect of each of the components of deprivation on neonatal and post-neonatal mortality. Despite these limitations, the DHS has been considered the most complete and reliable among the available surveys with data on neonatal mortality and household-level socioeconomic indicators.

In relation to methodological issues, it was not possible to fit a joint model for neonatal and post-neonatal mortality with period-specific coefficients. A joint model would allow us to test for differences in coefficients of the covariates of interest between the two periods. It would also be preferable to extend the SEM to include a model for the within-community standard deviation of the scores of the latent variable for household deprivation as a predictor of mortality, since the two-stage approach used in the models ignored the measurement error in the latent variable scores and their standard deviation.

Some considerations can be made regarding the theoretical framework that guided the inclusion of the covariates in the models. The theoretical framework used in this thesis is based on a development of Mosley and Chen's (1984) framework, involving a hierarchy between distal and proximal determinants. Victora et al. (1997) theorised that once the proximate determinants are included in the model, the distal determinants should have no association with the outcome, since they affect mortality only through the proximate variables. However, in the models, some socioeconomic determinants maintained a significant association with the outcome, meaning that some information about the proximal variables (for instance about family practices) was missing from the DHS dataset. Moreover, any attempt using path analysis to assess the mediating role of the proximal determinants was beyond the objective of this study.

Finally, an important limitation of this study is that, since the community in which one lives is not randomly assigned, unobserved household characteristics such as risk aversion may be correlated with both the level of deprivation in the community and the probability of infant mortality. Unfortunately, the data do not permit the more conservative fixed effects assumption, and in any case we argue that a household's residential location can be considered the result of a constrained choice, for instance due to economic resources.

5.9) Conclusion

This chapter explored the role of absolute deprivation, relative deprivation and deprivation inequality as predictors of neonatal and post-neonatal mortality in Bolivia. Beyond adding evidence to the field of socioeconomic determinants of neonatal and post-neonatal mortality in the context of a middle-income country, this analysis proposed a methodological improvement to the measurement of deprivation, since a latent variable approach allowed for taking into account the measurement error that may bias the estimates of the coefficients, which is an issue that typically arises while using other measures such as the DHS wealth index. Moreover, to my knowledge no previous study has proposed a decomposition of household deprivation into its household- and community-level components and assessed their effect on mortality. This study also explored different definitions of areas in which relative deprivation and deprivation inequality were calculated, using both communities and municipalities as higher-level units in the multilevel models.

This chapter found support for the absolute-deprivation hypothesis for both neonatal and post-neonatal mortality, with a slightly higher gradient of association with post-neonatal mortality than with neonatal mortality. If infant mortality is considered to be the result of a "cumulative series of biological insults" (Mosley and Chen, 1984), the effects of inadequate housing conditions (Fink et al., 2011; Esrey, 1996; Epstein et al., 2013) might need a time span of longer than four weeks to be totally expressed. While the relative-deprivation hypothesis found no support for any component of infant mortality at the community level, relative deprivation calculated at the municipal level was significantly associated with post-neonatal mortality; the size of the area for which relative deprivation was calculated therefore affected the significance of its association with health outcomes (Wilkinson and Pickett, 2006). Larger areas such as municipalities might better reflect the extent of how hierarchical a society is, especially in a very segregated country such as Bolivia: in Chapter 4, Bolivia was found to have a low degree of variation in deprivation within communities. We cannot exclude the possibility that the association between the variables of interest and the mortality outcome is different in more unequal contexts. Finally, there is little evidence to support the deprivation-inequality hypothesis in the neonatal and post-neonatal periods.

Policies aimed at reducing neonatal and post-neonatal mortality in countries like Bolivia should therefore focus on satisfying basic needs related to housing conditions and living standards. Moreover, the implementation of programmes aimed at improving community-level factors, like the availability of electricity and the quality of water and sanitation, could play a role in both neonatal and post-neonatal mortality.

5.10) Appendix: Models for births within 5 years from the interview

Table 5.13: Estimates of the effect of the socioeconomic determinants on log-odds of a child death and 95% C.I.s; Model (d) for neonatal and post-neonatal periods for births within 5 years from the interview

Model (d)		Neonatal period		Post-neonatal period	
Determinant	Parameter	Coeff.	95% CI	Coeff.	95% CI
Relative deprivation	$\lambda^*_{wi,W}$	0.07	[-0.03; 0.17]	-0.01	[-0.08; 0.08]
PSU-level mean deprivation	$\lambda^*_{wi,B}$	0.11	[0.02; 0.21]	0.03	[-0.05; 0.12]
Deprivation inequality	$\lambda_{wi,ineq}$	0.21	[-0.20; 0.61]	-0.00	[-0.35; 0.33]
Paternal occupation [ref. Not working or absent]	Blue-collar	-0.02	[-0.24; .023]	-0.05	[-0.22; 0.11]
	White- or pink-collar	0.01	[-0.22; 0.26]	-0.16	[-0.35; 0.01]
Maternal education	Years of education	-0.02	[-0.32; 0.00]	-0.02	[-0.03; -0.00]
Indigenous [ref. Not indigenous]	Indigenous	0.13	[-0.06; 0.34]	-0.07	[-0.24; 0.06]
Distance to the closest municipal capital	Distance	0.00	[-0.60; 0.50]	0.20	[-0.30; 0.60]
Regions [ref. La Paz]	Chuquisaca	-0.22	[-0.49; 0.04]	-0.52	[-0.82; -0.27]
	Cochabamba	-0.02	[-0.23; 0.19]	0.02	[-0.14; 0.18]
	Oruro	-0.12	[-0.38; 0.13]	0.10	[-0.08; 0.28]
	Potosí	0.13	[-0.07; 0.35]	0.11	[-0.05; 0.28]
	Tarija	-0.15	[-0.48; 0.17]	-0.36	[-0.64; -0.07]
	Santa Cruz	-0.32	[-0.58; -0.07]	-0.30	[-0.51; -0.10]
	Beni	-0.32	[-0.68; 0.01]	-0.29	[-0.58; -0.04]
	Pando	-0.41	[-0.93; 0.04]	-0.11	[-0.41; 0.20]
Distance to health facilities [ref. Not a big problem]	Big problem	0.06	[-0.08; 0.20]	0.08	[-0.03; 0.19]
Time interval within post-neonatal period	Sub-period 2			-0.37	[-0.49; -0.26]
	Sub-period 3			-0.40	[-0.52; -0.29]

Note: coefficients for the intercepts are not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero.
Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

In the models involving no decomposition of the latent variable, λ^* is equal to 0.11, with 95% CI equal to [0.01; 0.22] for neonatal mortality, and to 0.07, with 95% CI equal to [0.00; 0.15] for post-neonatal mortality (Table 5.13).

5.11) Appendix: Models including maternal instead of paternal occupation

Table 5.14: Estimates of the effect of the socioeconomic determinants on log-odds of a child death and 95% C.I.s; Model (d) for neonatal and post-neonatal periods including maternal instead of paternal occupation

Model (d)		Neonatal period		Post-neonatal period	
Determinant	Parameter	Mean	95% CI	Mean	95% CI
Relative deprivation	λ_W^*	-0.01	[-0.07; 0.06]	0.03	[-0.03; 0.09]
PSU-level mean deprivation	λ_B^*	0.05	[-0.02; 0.13]	0.07	[0.01; 0.14]
Deprivation inequality	λ_{ineq}	0.12	[-0.20; 0.39]	-0.11	[-0.37; 0.17]
Maternal occupation [ref. Not working]	Blue-collar	0.14	[0.02; 0.26]	-0.09	[-0.19; 0.01]
	White- or pink-collar	-0.00	[-0.15; 0.11]	-0.08	[-0.19; 0.03]
Maternal education	Years of education	-0.02	[-0.04; -0.01]	-0.02	[-0.03; -0.01]
Indigenous [ref. Not indigenous]	Indigenous	0.10	[-0.03; 0.25]	-0.09	[-0.20; 0.06]
Distance to the closest municipal capital	Distance	-0.30	[-0.80; 0.20]	0.10	[-0.30; 0.40]
Regions [ref. La Paz]	Chuquisaca	-0.12	[-0.32; 0.06]	-0.29	[-0.48; -0.10]
	Cochabamba	-0.04	[-0.20; 0.11]	-0.03	[-0.16; 0.11]
	Oruro	-0.16	[-0.37; 0.03]	0.10	[-0.06; 0.25]
	Potosí	0.13	[-0.03; 0.28]	0.13	[-0.01; 0.27]
	Tarija	-0.14	[-0.37; 0.09]	-0.32	[-0.55; -0.11]
	Santa Cruz	-0.25	[-0.41; -0.08]	-0.26	[-0.43; -0.08]
	Beni	-0.23	[-0.47; -0.01]	-0.34	[-0.58; -0.11]
	Pando	-0.16	[-0.49; 0.16]	-0.07	[-0.34; 0.17]
Bolivian Health Reform (2002) [ref. Before]	After 2002	-0.13	[-0.22; -0.05]	-0.04	[-0.12; 0.03]
Distance to health facilities [ref. Not a big problem]	Big problem	0.03	[-0.06; 0.13]	0.07	[-0.01; 0.16]
Time interval within post-neonatal period	Sub-period 2			-0.40	[-0.50; -0.31]
	Sub-period 3			-0.35	[-0.44; -0.26]
Length of the chains		5,500		12,900	

Note: coefficients for the intercepts are not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero.
Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

As in Models (d) including paternal occupation, both coefficients λ_B^* are significant (p-value=0.08 in the neonatal period, p-value=0.01 in the neonatal period), while λ_B^* and λ_{ineq} are not significant in either period (Table 5.14). No remarkable differences are found in the other covariates: education is a significant predictor of both outcomes, indigenousness (p-value=0.08) and whether the birth took place after the implementation of the Health Reform (p-value<0.01) are associated with neonatal mortality, and distance to health facilities ((p-value=0.04) is a significant predictor of only post-neonatal mortality.

5.12) Appendix: Models specifying the indigenous group to which households belong

Table 5.15: Estimates of the effect of the socioeconomic determinants on log-odds of a child death and 95% C.I.s; Model (d) for neonatal and post-neonatal periods specifying the indigenous group to which households belong

Model (d)		Neonatal period		Post-neonatal period	
Determinant	Parameter	Mean	95% CI	Mean	95% CI
Relative deprivation	λ_W^*	0.00	[-0.07; 0.08]	0.03	[-0.03; 0.09]
PSU-level mean deprivation	λ_B^*	0.09	[0.02; 0.17]	0.07	[0.01; 0.13]
Deprivation inequality	λ_{ineq}	0.09	[-0.20; 0.40]	-0.10	[-0.35; 0.17]
Paternal occupation [ref. Not working or absent]	Blue-collar	-0.11	[-0.26; 0.09]	-0.10	[-0.24; 0.08]
	White- or pink-collar	-0.12	[-0.28; 0.07]	-0.14	[-0.31; 0.02]
Maternal education	Years of education	-0.02	[-0.03; -0.01]	-0.02	[-0.04; -0.01]
Indigenous [ref. Aymara]	Non-indigenous	-0.27	[-0.51; -0.03]	0.04	[-0.15; 0.23]
	Quechua	-0.19	[-0.43; 0.03]	-0.14	[-0.31; 0.04]
	Other indigenous	-0.12	[-0.45; 0.22]	-0.07	[-0.37; 0.21]
Distance to the closest municipal capital	Distance	-0.30	[-0.80; 0.20]	0.00	[-0.30; 0.40]
Regions [ref. La Paz]	Chuquisaca	0.00	[-0.30; 0.30]	-0.18	[-0.39; 0.04]
	Cochabamba	0.13	[-0.13; 0.39]	0.08	[-0.14; 0.27]
	Oruro	-0.11	[-0.33; 0.10]	0.14	[-0.03; 0.30]
	Potosí	0.29	[0.04; 0.53]	0.24	[0.03; 0.44]
	Tarija	-0.01	[-0.33; 0.29]	-0.29	[-0.55; -0.06]
	Santa Cruz	-0.14	[-0.43; 0.13]	-0.20	[-0.41; 0.02]
	Beni	-0.17	[-0.50; 0.15]	-0.26	[-0.55; -0.01]
	Pando	-0.03	[-0.39; 0.31]	-0.02	[-0.30; 0.25]
Bolivian Health Reform (2002) [ref. Before]	After 2002	-0.14	[-0.22; -0.05]	-0.04	[-0.12; 0.03]
Distance to health facilities [ref. Not a big problem]	Big problem	0.04	[-0.05; 0.15]	0.07	[-0.02; 0.16]
Time interval within post-neonatal period	Sub-period 2			-0.40	[-0.50; -0.31]
	Sub-period 3			-0.35	-0.44; -0.26]
Length of the chains		6,300		13,700	

Note: coefficients for the intercepts are not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero.

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

Since no significant differences are found in neonatal and post-neonatal mortality between Aymara, Quechua and other indigenous groups (Table 5.15), the binary variable for indigenous or non-indigenous has been kept in the models.

5.13) Appendix: Models including the interaction between community-level deprivation and the dummy variable for pre/post Bolivian health reform (2002)

Table 5.16: Estimates of the odds ratio of the socioeconomic determinants and corresponding p-values; model (d) for neonatal and post-neonatal periods including the interaction between the socioeconomic determinants of interest and the dummy variable for pre/post Bolivia health reform (2002)

		Neonatal period		**Post-neonatal period**	
Determinant	Parameter	Coef.	95% CI	Coef.	95% CI
Relative deprivation	λ_W^*	-0.08	[-0.20; 0.03]	0.04	[-0.04; 0.15]
Community-level mean deprivation	λ_B^*	0.10	[0.01; 0.19]	0.06	[-0.01; 0.14]
Deprivation inequality	λ_{ineq}	-0.13	[-0.55; 0.26]	-0.02	[-0.41; 0.36]
Paternal occupation [ref. Not working or absent]	Blue-collar	-0.16	[-0.32; 0.00]	-0.03	[-0.16; 0.12]
	White- or pink-collar	-0.16	[-0.33; 0.02]	-0.09	[-0.23; 0.05]
Maternal education	Years of education	-0.02	[-0.03; -0.01]	-0.02	[-0.03; -0.01]
Indigenous [ref. Not indigenous]	Indigenous	0.11	[-0.05; 0.26]	-0.07	[-0.21; 0.06]
Distance to the closest municipal capital	Distance	-0.30	[-0.80; 0.20]	0.10	[-0.30; 0.40]
Distance to health facilities [ref. Not a big problem]	Big problem	0.04	[-0.06; 0.15]	0.08	[-0.01; 0.16]
Regions [ref. La Paz]	Chuquisaca	-0.17	[-0.37; 0.04]	-0.26	[-0.44; -0.07]
	Cochabamba	-0.05	[-0.22; 0.12]	-0.03	[-0.17; 0.11]
	Oruro	-0.20	[-0.42; 0.00]	0.10	[-0.06; 0.26]
	Potosí	0.12	[-0.05; 0.28]	0.14	[-0.00; 0.27]
	Tarija	-0.16	[-0.43; 0.09]	-0.31	[-0.54; -0.09]
	Santa Cruz	-0.30	[-0.51; -0.09]	-0.23	[-0.40; -0.07]
	Beni	-0.29	[-0.58; -0.04]	-0.29	[-0.54; -0.07]
	Pando	-0.15	[-0.48; 0.16]	-0.04	[-0.28; 0.21]
Bolivian health reform (2002) [ref. Before]	After 2002	-0.57	[-0.91; -0.35]	-0.03	[-0.33; 0.27]
Interaction terms	After 2002 * λ_W^*	-0.13	[-0.27; 0.01]	0.04	[-0.07; 0.16]
	After 2002 * λ_B^*	0.00	[-0.03; 0.03]	0.00	[-0.03; 0.03]
	After 2002 * λ_{ineq}	0.41	[-0.08; 0.95]	-0.16	[-0.74; 0.40]
Time interval within post-neonatal period	Sub-period 2			-0.40	[-0.49; -0.31]
	Sub-period 3			-0.35	[-0.44; -0.26]
Length of the chains		40,100		75,400	

Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

5.14) Appendix: Models with an increased chain length of 100,000 iterations

Table 5.17: Estimates of the effect of the socioeconomic determinants on log-odds of a child death and 95% C.I.s; Model (d) for neonatal and post-neonatal periods with an increased chain length of 100,000 iterations

Model (d)		Neonatal period		Post-neonatal period	
Determinant	Parameter	Mean	95% CI	Mean	95% CI
Relative deprivation	λ_W^*	0.01	[-0.07; 0.08]	0.03	[-0.04; 0.09]
PSU-level mean deprivation	λ_B^*	0.10	[0.03; 0.17]	0.04	[-0.01; 0.11]
Deprivation inequality	λ_{ineq}	0.10	[-0.21; 0.40]	-0.10	[-0.36; 0.17]
Paternal occupation [ref. Not working or absent]	Blue-collar	-0.13	[-0.30; 0.04]	-0.06	[-0.20; 0.07]
	White- or pink-collar	-0.14	[-0.31; 0.05]	-0.12	[-0.27; 0.02]
Maternal education	Years of education	-0.02	[-0.03; -0.01]	-0.02	[-0.03; -0.01]
Indigenous [ref. Not indigenous]	Indigenous	0.10	[-0.01; 0.22]	0.04	[-0.06; 0.14]
Distance to the closest municipal capital	Distance	-0.30	[-0.80; 0.20]	0.10	[-0.30; 0.40]
Regions [ref. La Paz]	Chuquisaca	-0.17	[-0.37; 0.02]	-0.23	[-0.42; -0.06]
	Cochabamba	-0.05	[-0.21; 0.11]	-0.02	[-0.16; 0.11]
	Oruro	-0.19	[-0.39; 0.01]	0.11	[-0.04; 0.26]
	Potosí	0.11	[-0.05; 0.27]	0.14	[0.01; 0.27]
	Tarija	-0.19	[-0.41; 0.03]	-0.23	[-0.45; -0.03]
	Santa Cruz	-0.31	[-0.49; -0.13]	-0.18	[-0.33; -0.03]
	Beni	-0.31	[-0.56; -0.07]	-0.21	[-0.42; -0.01]
	Pando	-0.18	[-0.48; 0.10]	0.04	[-0.19; 0.26]
Bolivian Health Reform (2002) [ref. Before]	After 2002	-0.14	[-0.22; -0.05]	-0.04	[-0.12; 0.03]
Distance to health facilities [ref. Not a big problem]	Big problem	0.04	[-0.06; 0.14]	0.07	[-0.02; 0.16]
Time interval within post-neonatal period	Sub-period 2			-0.40	[-0.49; -0.31]
	Sub-period 3			-0.35	[-0.44; -0.26]

Note: coefficients for the intercepts are not reported. Estimates are posterior means and 95% credible intervals (2.5 and 97.5 percentiles). In bold if the 95% C.I. does not contain zero.
Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

5.15) Appendix: Models including the DHS wealth index instead of the latent variable for household deprivation

The model including the DHS wealth index as a covariate instead of the latent variable for household deprivation is similar to the model of Equation (5.5), and its equation is

$$\mathrm{logit}\left(p_{ijk}\right) = \boldsymbol{\beta}^T \boldsymbol{x}_{ijk} + \lambda_{wi,W}\left(wealth\_index_{jk}^{(hh)} - \overline{wealth\_\imath ndex}_k^{(PSU)}\right) + \lambda_{wi,B}\overline{wealth\_\imath ndex}_k^{(PSU)} + \lambda_{wi,ineq}\mathrm{SD}_k\left(wealth\_index_{jk}^{(hh)}\right) + v_{jk}^{(hh)} + v_k^{(PSU)} \quad (5.6)$$

where $\lambda_{wi,W}$ is the effect of the departure of each household's score in deprivation from their PSU's mean, $\lambda_{wi,B}$ is the effect of the PSU mean score in the DHS wealth index, $\lambda_{wi,ineq}$ is the effect of the PSU-level standard deviation of the DHS wealth index, $\boldsymbol{x}_{ijk}$ is a vector of covariates, $v_{jk}^{(hh)} \sim N(0, \sigma_v^{2\,(hh)})$ is the household residual, and $v_k^{(PSU)} \sim N(0, \sigma_v^{2\,(PSU)})$ is the PSU-level random effect. The coefficients $\lambda_{wi,W}^*$ and $\lambda_{wi,B}^*$ shown in Table 5.17 are standardised. Since this model includes the derived wealth index rather than a latent variable, it is a standard three-level logistic model.

In comparison to the SEM model including the latent variable for household deprivation, many differences can be found in the significance of the coefficients. The largest difference is related to the coefficient $\lambda_{wi,B}^*$ of PSU-level deprivation in the post-neonatal period, which has a borderline p-value equal to 0.07 (the p-value is equal to 0.04 in the SEM). Other differences can be found in the effects of the other socioeconomic determinants: here paternal occupation is never significant, distance to health facilities and whether the birth took place before or after 2002 are not significant predictors of post-neonatal mortality, and the Chiquisaca, Potosí, Tarija and Pando regions do not present significant differences in neonatal mortality in comparison to La Paz.

Table 5.18: Coefficients and 95% C.I.s; Model (d) for neonatal and post-neonatal periods including the DHS wealth index instead of the latent variable for household deprivation

Model (d)		Neonatal period		Post-neonatal period	
Determinant	Parameter	Coeff.	95% CI	Coeff.	95% CI
Relative deprivation	$\lambda^*_{wi,W}$	-0.02	[-0.13; 0.08]	-0.04	[-0.15; 0.07]
PSU-level mean deprivation	$\lambda^*_{wi,B}$	-0.21	[-0.36; -0.06]	-0.13	[-0.28; 0.01]
Deprivation inequality	$\lambda_{wi,ineq}$	0.10	[-0.60; 0.79]	-0.15	[-0.83; 0.53]
Paternal occupation [ref. Not working or absent]	Blue-collar	-0.29	[-0.64; 0.06]	-0.13	[-0.50; 0.25]
	White- or pink-collar	-0.27	[-0.65; 0.10]	-0.25	[-0.66; 0.16]
Maternal education	Years of education	-0.04	[-0.07; -0.01]	-0.05	[-0.08; -0.02]
Indigenous [ref. Not indigenous]	Indigenous	0.24	[-0.02; 0.50]	0.11	[-0.15; 0.37]
Distance to the closest municipal capital	Distance	-0.64	[-1.68; 0.39]	0.12	[-0.75; 1.00]
Regions [ref. La Paz]	Chuquisaca	-0.31	[-0.70; 0.09]	-0.60	[-1.03; -0.16]
	Cochabamba	-0.07	[-0.40; 0.26]	-0.07	[-0.40; 0.26]
	Oruro	-0.40	[-0.82; 0.02]	0.27	[-0.10; 0.62]
	Potosí	0.22	[-0.10; 0.54]	0.33	[0.02; 0.63]
	Tarija	-0.37	[-0.85; 0.11]	-0.54	[-1.07; -0.04]
	Santa Cruz	-0.68	[-1.07; -0.28]	-0.50	[-0.88; 0.11]
	Beni	-0.65	[-1.19; -0.10]	-0.55	[-1.09; -0.01]
	Pando	-0.42	[-1.06; 0.22]	0.09	[-0.47; 0.64]
Bolivian Health Reform (2002) [ref. Before]	After 2002	-0.29	[-0.47; -0.11]	-0.10	[-0.29; 0.09]
Distance to health facilities [ref. Not a big problem]	Big problem	0.05	[-0.16; 0.26]	0.17	[-0.05; 0.38]
Time interval within post-neonatal period	Sub-period 2			-1.01	[-1.25; -0.77]
	Sub-period 3			-0.89	[-1.12; -0.66]

Note: coefficients for the intercepts are not reported.
Source: Demographic and Health Surveys. Sample size: 17,478 children, 5,849 households, 988 communities

6. Conclusions

6.1) Main contributions and findings

This thesis was motivated by the lack of studies on the socioeconomic determinants of neonatal and post-neonatal mortality (Neal, 2009). While overall under-five mortality has decreased substantially over the last decades, the pace of the decline in neonatal mortality rates has been slower (Pathirana, 2016), and this trend might be explained by a differential between neonatal and post-neonatal mortality determinants.

The aim of this thesis was to analyse the association between a set of socioeconomic factors and neonatal and post-neonatal mortality, focusing on different patterns of association with mortality between the neonatal and post-neonatal periods, both in a country-level longitudinal study (Chapter 3) and in a micro-level cross-sectional study, for the case of Bolivia (Chapter 5). This thesis also involved a study investigating the factors associated with the geographical clustering of deprivation in Bolivia (Chapter 4), as deprivation is seen as a major determinant of infant mortality in Chapters 3 and 5. Deprivation was the determinant of interest, and was conceptualised as a lack of basic needs related to housing conditions; therefore, non-monetary measures of deprivation based on observed indicators related to living standards were used in this thesis. The main methodological contributions of this thesis are related to the measurement of household deprivation, the development of a multilevel structural equation approach to studying the clustering of deprivation, and the assessment of the effects of deprivation both at the individual and the area level on mortality. In the next sections the main empirical and methodological contributions from the three studies highlighted in Section 1.1 are summarised, before discussing the main limitations, policy implications, and the directions for future research.

6.1.1) Different patterns of association of the three manifestations of deprivation with neonatal mortality, in comparison with post-neonatal mortality

Socioeconomic determinants of neonatal and post-neonatal mortality have rarely been compared in the literature (Neal, 2009). For instance, little research exists on the different effects of relative deprivation in the neonatal and post-neonatal period, and all of the existing studies are focused on high-income countries (Lhila and Simon, 2010). Differences in the patterns of association between socioeconomic determinants and mortality occurring between the neonatal and post-neonatal periods might be one of the reasons for the slower pace of decline of neonatal mortality rates in comparison to overall under-five mortality observed in many areas of the world over the last decades (Figure 1.2). Listed below are the main findings related to the association between the mortality outcomes and absolute deprivation, relative deprivation, and deprivation inequality.

Absolute deprivation: The findings from Chapters 3 and 5 are consistent in assessing deprivation as a major determinant of both neonatal and post-neonatal mortality. In particular, in Chapter 3, in the context of low- and middle-income countries, the two components of infant mortality were found to be significantly associated with GDP per capita and access to clean water, which is a major cause of water-borne diseases such as those causing diarrhoea (Fewtrell et al., 2005). In Chapter 5, two main findings are related to absolute deprivation. Firstly, inadequate housing conditions linked, among other things, to the quality of sanitation, water, and indoor air pollution, were found to significantly predict both neonatal and post-neonatal mortality. Secondly, community-level absolute deprivation was found to be a significant predictor of neonatal and post-neonatal mortality. These findings are consistent with a large body of literature investigating the association between deprivation and neonatal and post-neonatal mortality at the country level (Wagstaff, 2002; United Nations Fund for Population et al., 1999) and at the micro level (Fink et al., 2011; Epstein et al., 2013; Van de Poel, 2009; Jaadla and Puur, 2016).

Consistent with the literature (Bobak and Leon, 1992; Bobak and Leon, 1999), household- and community-level absolute deprivation were found to have a stronger association with post-neonatal mortality than with neonatal mortality at the micro level in Chapter 5. The shorter length of exposure might be among the reasons for this pattern, since the effects of health-damaging environmental factors might need more than four weeks to cause death among newborns. Another reason might be the fact that neonatal mortality is more strongly associated with endogenous determinants such as preterm birth complications or congenital diseases (Black et al., 2010; Taskaya and Demirkiran, 2017).

Relative deprivation: In Chapter 7, relative deprivation was found to have a significant association with post-neonatal mortality in Bolivia when deprivation was calculated at the municipal level. An increased post-neonatal mortality risk among households with a higher level of deprivation may be due to such households lacking material resources; for instance, having no access to clean water and sanitation can affect post-neonatal health outcomes (Fewtrell et al., 2005). On the other hand, neonatal mortality might not be affected by social comparisons since this component is more strongly associated with intrauterine and delivery factors (Black et al., 2010). These findings add evidence to the almost unexplored field of the association between relative deprivation and the components of infant mortality in the context of low- and middle-income countries, since the great majority of the published studies investigate the effect of relative deprivation on adult health in high-income countries (Kayode et al., 2014).

However, relative deprivation was not found to be a significant predictor of neonatal and post-neonatal mortality when calculated at the community level. We found evidence that the size of the area for which inequality in the distribution of deprivation is calculated is important, since calculating relative deprivation and deprivation inequality at the community level might underestimate the scale of social stratification, and bias the estimates of their association with neonatal and post-neonatal mortality. Wilkinson and Pickett (2006) highlighted the importance of the size of the area for which inequality is calculated, noting that small areas may not reflect how hierarchical a society is; in their literature review, they found studies in which income inequality was calculated in large areas to be more supportive of the hypothesis that the higher the inequality, the worse the health outcomes of the population. Even when they live in homogeneous communities, poorer households might still be aware of the existence of richer groups in other areas (Bourdieu, 1984; Canadine, 1998). Bolivian municipalities are on average four times larger than communities, and might therefore include enough households to consider social comparisons with richer households.

Deprivation inequality: Deprivation inequality was not found to have a significant association with neonatal and post-neonatal mortality in Chapter 5, as in the only study, to my knowledge, that has measured inequality at the neighbourhood level (Szwarcwald et al., 2002). This might be explained by the fact that in low- and middle-income countries many households lack the resources for an adequate living standard and environmental factors related to housing conditions might therefore be more important in determining health. However, inequality might affect mortality in the context of high-income countries, where basic needs are satisfied for a high proportion of the population, by fostering the erosion of social cohesion and causing stress that induces mothers to smoke (Wilkinson, 1996; Reagan, 2007). Furthermore, this thesis finds no support for the hypothesis that income inequality is a significant determinant of health in peripheral countries (Moore, 2006).

6.1.2) Proposal of an alternative to the DHS wealth index for measuring deprivation

In this thesis, household deprivation is conceptualised as a lack of basic needs related to living standards and housing conditions. As seen in Section 2.3, the aim of this thesis was to assess the net effect of housing conditions on mortality outcomes, while controlling for the other dimensions of poverty in Sen's (1989) capability approach framework. Housing conditions are associated with health and education, and are therefore strongly related to poverty (Garriga et al., 2013; Bosch et al., 2001; Falkingham and Nemazie, 2002).

The approach for measuring deprivation used in this thesis is similar to that used in the construction of the DHS wealth index (Rutstein and Johnson, 2004). However, several drawbacks to the use of the DHS wealth index have been highlighted in the literature. First, it does not take into account the categorical nature of the observed indicators, treating all of the items as continuous (Howe et al., 2008). Second, the use of the DHS wealth index as an explanatory variable in regression models might bias the estimate of the association, since it ignores the measurement error that arises from constructing an index from a set of items (Muthén, 1997). Finally, the construction of the DHS wealth index does not involve prior investigation of the correlation matrix of the observed indicators, potentially leading to the use of weakly correlated items that could belong to different dimensions (Kolenikov and Angeles, 2004).

A latent variable approach was proposed in Chapters 4 and 5, which allows us to address the above-mentioned issues. By specifying a logit link between the latent variable for household deprivation and the response probabilities for items in the measurement model, SEM is suitable for binary observed indicators. An important feature of SEM is that it reduces the bias of the estimates of the association between the latent variable and other variables; since latent variables are not measured directly, they do not have any measurement error associated with them (Muthén, 1997). Before constructing the latent variable, the investigation of the correlation matrix was carried out and items with a very low or very high correlation were excluded from the measurement model, in order to avoid multicollinearity and to have a coherent set of indicators measuring household deprivation. Sensitivity analyses were carried out in Chapters 4 and 5, running the same models including the DHS wealth index instead of the latent variable for household deprivation. Differences in the results were observed, which may be due to the use of a different set of items in the construction of the indices, and the fact that the DHS wealth index does not take into account the measurement error.

6.1.3) A generalised modelling approach for the study of deprivation segregation

In Chapter 4, a general SEM approach for the study of geographical segregation was proposed. This method extends the multilevel modelling approach proposed by Goldstein and Noden (2003) to handle constructs measured by multiple indicators. While traditional segregation indices are descriptive and fail to take into account the probabilistic component resulting from the sampling process, a multilevel model approach overcomes these limitations, by separating the component of the observed proportion that is due to sampling variation. By estimating standard errors, statistical inferences can be made about segregation (Goldstein and Noden, 2003). Previous papers have used multilevel modelling to assess social segregation in schools and areas using a single binary socioeconomic indicator (Goldstein and Noden, 2003; Leckie et al., 2012). The main contribution of Chapter 4 is that the outcome of interest, household deprivation, was treated as a continuous latent variable, measured by a set of multiple correlated indicators. The decomposition of the latent variable into its between- and within-community components allowed us to measure the segregation of deprivation by estimating the higher-level variance parameter in the multilevel model. This allowed the assessment of the proportion of variation in the characteristic of interest that is due to the grouping of individuals within areas: the larger it is, the more segregated the areas are. Bolivia was found to have a high level of segregation of deprivation, since the main source of variation in deprivation was due to differences across communities, rather than within communities. This result is consistent with another study that found a relatively low level of inequality in rural Bolivian communities (Castellanos, 2007). Moreover, this approach enabled us not just to quantify the extent of segregation but also to model patterns of segregation as functions of contextual factors, allowing us to investigate a more general set of research questions in the study of segregation (Leckie et al., 2012). Five contextual factors (ethnicity, education, administrative region, distance to urban centres, and drought-induced migration) were found to be significantly associated with the segregation of deprivation.

6.2) Limitations of these studies

In addition to the specific limitations related to the data and methods of each of the three studies included in Chapters 3, 4, and 5, some overall limitations of this thesis must be highlighted.

6.2.1) Generalization of the findings

The first limitation is related to the fact that the findings of this thesis are limited to a context of widespread deprivation, and it would be a mistake to generalize such findings to contexts with better living standards.

In Bolivia and in the majority of the countries included in the sample analysed in Chapter 3, many households lack the resources for an adequate living standard. In such contexts, children living in poor conditions might be more exposed, among other things, to water-borne diseases due to the unavailability of clean water and adequate sanitation, and to respiratory problems caused by indoor air pollution. For instance, the fact that deprivation inequality was not found to be a significant predictor of neonatal and post-neonatal mortality should not be generalised to countries with better living standards. In fact, Wilkinson (1994) argues that inequality in the distribution of wealth might have an influence on health only in countries where basic needs are satisfied. Moreover, as highlighted in Chapter 4, there is a low level of inequality in deprivation within Bolivian communities, and therefore social comparisons with its neighbours are not driven by dramatic differences in living standards. The possibility that relative deprivation and deprivation inequality are significant predictors of the components of infant mortality in more unequal contexts cannot be excluded.

Finally, when using datasets from other countries, deprivation might be measured by a different set of items to those selected in Chapter 4. The items used in the construction of the latent variable for household deprivation were selected after investigation of the correlation matrix among all of the items available, and the correlations among items could be different in other countries, therefore leading to a different selection of items to measure deprivation. In other contexts, the ownership of some items might have stronger or weaker power to discriminate households in relation to their level of deprivation.

6.2.2) Causal paths

This thesis only explores associations between the determinants of interest and mortality, and no attempt has been made to establish causal paths leading from deprivation to infant health outcomes. For instance, in Chapter 5 relative deprivation calculated at the municipal level was found to have a significant association with post-neonatal mortality in Bolivia. However, the hypotheses related to the lack of material resources and to stress-induced maternal smoking have only been considered as potential pathways leading from relative deprivation to post-neonatal mortality, since the data and methods used in this thesis do not allow us to assess causality. The same is true in Chapter 3, where water-borne diseases and maternal health during pregnancy are only hypothesised as being potential pathways through which access to clean water can affect neonatal and post-neonatal mortality. Moreover, any attempt at using path analysis to assess the proximal determinants as mediators between the socioeconomic distal determinants and the mortality outcomes was beyond the objectives of this study.

6.2.3) Theoretical framework

Another limitation is related to the theoretical framework used in this thesis, which is based on a development of Mosley and Chen’s (1984) framework, involving a hierarchy between socioeconomic distal and proximal determinants. Victora et al. (1997) theorised that once the proximate determinants are included in the model, the distal determinants should have no association with the outcome, since they affect mortality only through the proximate variables. However, in the micro-level analysis including proximal variables in Chapter 5, some socioeconomic determinants maintained a significant association with the outcome, meaning that some information (for instance about family practices) was missing from the DHS dataset.

Moreover, especially in the analyses in Chapter 3, the selected variables do not fully describe the set of determinants of neonatal and post-neonatal mortality considered in the theoretical framework. This is mainly due to the fact that some factors related to social norms and cultural beliefs are difficult to capture by means of variables measured at the country level, while other variables had unacceptable rates of missing data. Finally, another consideration must be made in relation to the fact that some variables might have a different association with the mortality outcomes in rural and urban areas. For instance, access to clean water and sanitation might be associated with health hazards due to poor infrastructure and high population density in urban areas, while they might be associated with improved health outcomes in rural areas (World Health Organization, 2006).

6.2.4) Conceptualisation and measure of social comparisons

In this thesis, social comparisons were assessed as the difference between each household's deprivation level and the mean level of their community. However, there is no evidence that social comparisons are only driven by housing conditions and living standards. Other social factors could affect the feelings of inferiority of an individual compared to their neighbours and might be investigated (Coburn, 2004). For instance, income or social networks might be more important variables than household deprivation for the creation of a social hierarchy to guide social comparisons (Zoomers, 2006).

Moreover, in Chapter 5, we found evidence that relative deprivation has a different magnitude of association with mortality outcomes depending on the size of the area in which it is calculated. However, the data allow us to measure relative deprivation only at two different levels (communities and municipalities), implying a different conceptualization of social comparisons. More evidence is needed to assess whether households compare themselves with the closest neighbours within their community, which in Bolivia tend to have similar levels of deprivation, or to households living further away in their municipality or even in broader areas.

6.3) Policy implications

Overall, this thesis highlighted that the satisfaction of basic needs is a fundamental determinant of neonatal and post-neonatal mortality, in the context of low- and middle-income countries (Chapters 3 and 5). Policies oriented towards the reduction of neonatal and post-neonatal mortality should focus on the reduction of poverty and the improvement of housing conditions and living standards. Moreover, the implementation of programmes aimed at the improvement of community-level factors, such as the availability of electricity and the extension of a clean water supply, can have an impact on infant health outcomes (Van de Poel, 2009; Jaadla and Puur, 2016). As highlighted in Chapter 5, the absolute level of deprivation at the household and community level has a stronger association with post-neonatal than with neonatal mortality; this result can partly explain the slower pace of decrease of neonatal mortality rates in comparison with the pace of mortality occurring later in childhood, observed in many areas of the world over the last decades (UNICEF et al., 2015).

Chapter 4 provided indications for social policies aimed at reducing spatial unevenness in the distribution of deprivation, by identifying the contextual factors linked to the segregation of deprivation. For instance, policies aimed at raising the mean level of male and female education in the most deprived communities could reduce the difference in deprivation with better off communities. The segregation of deprivation is associated, among other things, with social exclusion, lower access to public services, and diminished opportunities for the development of human capital (Silver, 1994); segregation can also affect health indicators, since contexts of concentrated deprivation are more likely to have higher exposure to infectious diseases and higher mortality rates (Fiscella and Franks, 1997). Reducing inequality across Bolivian communities could therefore be a crucial intervention for improving health indicators.

6.4) Direction for further research

The field of socioeconomic determinants of neonatal mortality (and how they differ from post-neonatal determinants) remains largely unexplored, and more research is needed on the role of the distribution of deprivation, especially in the context of low- and middle-income countries. For instance, in this thesis there is evidence that the size of the area for which relative deprivation and deprivation inequality are calculated might affect the estimates of their association with health outcomes. However, more studies are needed in order to assess whether calculating relative deprivation and deprivation inequality in broader areas leads to more evidence for the hypothesis that higher inequality is associated with negative health outcomes (Wilkinson and Pickett, 2006).

The DHS datasets do not provide any data on income; it would be of interest to assess whether it is more the distribution of income or of non-monetary deprivation that has an influence on neonatal and post-neonatal mortality. While in this thesis we made use of indicators assessing deprivation from a broader perspective (Grosse et al., 2005), social comparisons might still be driven by monetary measures such as income or consumption expenditure.

Further research might also involve the study of causal paths leading from deprivation to infant health outcomes. For instance, more theoretical reasons for linking relative deprivation with infant health outcomes are needed, since the pathway of stress-induced maternal smoking is unlikely in some low- and middle-income countries like Bolivia (Albalak et al., 1999).

It might also be of interest to study the association between deprivation and other infant health outcomes beyond mortality, like birth weight or infant morbidity. While mortality is the extreme result of exposure to a “cumulative series of biological insults” (Mosley and Chen, 1984), these measures might be predictive of the quality of life of children who survive their first birthday (Shrimpton, 2003; Saigal and Doyle, 2008).

Methodologically, the models seen in the micro-level analysis could be improved, since a joint model for neonatal and post-neonatal mortality would allow for testing for differences in the effects of deprivation between the two periods. Finally, the use of specialist Bayesian software might allow the simultaneous estimation of the within-cluster standard deviation of the latent variable for household deprivation and its effect on mortality rather than the two-stage estimation approach adopted in this thesis.

References

Aaby, P., Roth, A., Ravn, H., Napirna, B. M., Rodrigues, A., Lisse, I. M., & Biering-Sørensen, S. (2011). Randomized trial of BCG vaccination at birth to low-birth-weight children: beneficial nonspecific effects in the neonatal period?. *Journal of Infectious Diseases, 204(2), 245-252.*

Adamu, Y. M., & Salihu, H. M. (2002). Barriers to the use of antenatal and obstetric care services in rural Kano, Nigeria. *Journal of obstetrics and gynaecology*, *22*(6), 600-603.

Albalak, R., Frisancho, A. R., & Keeler, G. J. (1999). Domestic biomass fuel combustion and chronic bronchitis in two rural Bolivian villages. *Thorax, 54*(11), 1004-1008.

Albo, X. (1994). Ethnic violence: the case of Bolivia. *The culture of violence*, 119-143.

Aleshina, N., & Redmond, G. (2005). How high is infant mortality in Central and Eastern Europe and the Commonwealth of Independent States?. Population studies, 59(1), 39-54.

Alfonso, M. (2008) Girls just want to have fun? Sexuality, pregnancy, and motherhood among Bolivian teenagers. *IDB working papers n.517*

Alkema, L., & New, J. R. (2014). Global estimation of child mortality using a Bayesian B-spline bias-reduction model. *The Annals of Applied Statistics, 8*(4), 2122-2149.

Alkire, S., & Santos, M. (2010). Acute Multidimensional Poverty: A New Index for Developing Countries. *IDEAS Working Paper Series from RePEc*.

Alkire, S., & Santos, M. E. (2014). Measuring Acute Poverty in the Developing World: Robustness and Scope of the Multidimensional Poverty Index. *World Development, 59,* 251-274.

Allen, R., Burgess, S., Davidson, R., & Windmeijer, F. (2015). More reliable inference for the dissimilarity index of segregation. *The econometrics journal, 18(1), 40-66.*

Allison, P.D. (1978). Measures of inequality. *American Sociological Review 43: 865-880.*

Amara, M., & El Lahga, A. (2016). Tunisian constituent assembly elections: how does spatial proximity matter?. *Quality & Quantity*, *50*(1), 65-88.

Amarasinghe, U., Samad, M., & Anputhas, M. (2005). Spatial clustering of rural poverty and food insecurity in Sri Lanka. *Food Policy, 30*(5), 493-509.

Anaya, J. A. M. (1987). Estabilización y nueva política económica en Bolivia. *El Trimestre Económico, 54,* 179-211.

Andersen, L. E. (2002). Rural-urban migration in Bolivia: Advantages and disadvantages. *Instituto de Investigaciones Socio-Económicas, Universidad Católica Boliviana; Documento de Trabajo No.05/02*.

Arbuckle, J. (2009). Amos 18 user's guide. *Armonk, NY: SPSS incorporated*.

Arntzen, A., Mortensen, L., Schnor, O., Cnattingius, S., Gissler, M., & Andersen, A.-M. N. (2008). Neonatal and postneonatal mortality by maternal education—a population- based study of trends in the Nordic countries, 1981–2000. *European Journal of Public Health, 18*(3), 245-251.

Arokiasamy, P., & Gautam, A. (2008). Neonatal mortality in the empowered action group states of India: trends and determinants. *Journal of biosocial science, 40(2), 183-201.*

Asparouhov, T., & Muthén, B. (2010). Bayesian analysis of latent variable models using Mplus. *Available at: https://www.statmodel.com/download/BayesAdvantages2018.pdf*

Atkinson, A. B. (2003). Multidimensional deprivation: contrasting social welfare and counting approaches. *The Journal of Economic Inequality*, *1*(1), 51-65.

Baird, S., Friedman, J., & Schady, N. (2011). Aggregate income shocks and infant mortality in the developing world. *Review of Economics and statistics, 93*(3), 847-856.

Balderrama, C. (2011). Rural migration in Bolivia: the impact of climate change, economic crisis and state policy. *IIED; No. 31*.

Balestrino, A., & Sciclone, N. (2001). Should we use functionings instead of income to measure well-being? Theory, and some evidence from Italy. *Rivista internazionale di scienze sociali, 3-22.*

Balsa, A. I., French, M. T., & Regan, T. L. (2014). Relative deprivation and risky behaviors. *Journal of Human Resources 49.2*, 446-471.

Bang, A. T., Bang, R. A., Baitule, S. B., Reddy, M. H., & Deshmukh, M. D. (1999). Effect of home-based neonatal care and management of sepsis on neonatal mortality: field trial in rural India. *The lancet, 354(9194), 1955-1961.*

Baqui, A. H., Arifeen, S. E., Williams, E. K., Ahmed, S., Mannan, I., Rahman, S. M., & Black, R. E. (2009). Effectiveness of home-based management of newborn infections by community health workers in rural Bangladesh. *The Pediatric infectious disease journal, 28(4), 304*.

Barnes, D. F. (1988). *Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries.* Boulder, CO: Westview Press.

Barragán, R., & Roca, J. L. (2005). Regiones y poder constituyente en Bolivia : una historia de pactos y disputas. *Cuaderno de futuro, 21. La Paz, Bolivia: PNUD.*

Barro, R. J., & McCleary, R. (2003). *Religion and economic growth*. National Bureau of Economic Research.

Bartholomew, D. J., Knott, M., & Moustaki, I. (2011). Latent variable models and factor analysis: A unified approach. *John Wiley & Sons*; *Vol. 904.*

Bastien, J. W. (1982). Exchange between Andean and western medicine. *Social Science & Medicine, 16*(7), 795-803.

Bell, W. (1954). A probability model for the measurement of ecological segregation. *Social Forces*, 357-364.

Bello, A., & Rangel, M. (2000). Etnicidad," raza" y equidad en América Latina y el Caribe. *Comisión Económica para América Latina y el Caribe; LC/R.1967/Rev.1*.

Bengtsson, T., & Dribe, M. (2010). Quantifying the Family Frailty Effect in Infant and Child Mortality by Using Median Hazard Ratio (MHR) The Case of Rural Sweden, 1766–1895. *Historical Methods, 43*(1), 15-27.

Benton, J. (1993). The role of womens organisations and groups in community development. A case study of Bolivia. *USAid working papers; Document No. 127039; Available at: https://www.popline.org/node/339234*

Bhalotra, S. (2008). Childhood Mortality and Economic Growth. *IDEAS Working Paper Series from RePEc*.

Bibby, J. (1975). Methods of measuring mobility. *Quality and Quantity, 9*(2), 107-136.

Bicego, G. T. (1996). *Infant and child mortality*. Calverton: Calverton : Macro International.

Billings, D. L., Crane, B. B., Benson, J., Solo, J., & Fetters, T. (2007). Scaling-up a public health innovation: A comparative study of post-abortion care in Bolivia and Mexico. *Social Science & Medicine, 64*(11), 2210-2222.

Bird, P. (2013). *Social gradients in child health and development in relation to income inequality*. *Who benefits from greater income equality?* (Doctoral dissertation, University of York).

Birol, F. (2007). Energy economics: a place for energy poverty in the agenda? Energy Journal – Cambridge M.A., 28(3), 1.

Black, R. E., Cousens, S., Johnson, H. L., Lawn, J. E., Rudan, I., Bassani, D. G., Eisele, T. (2010). Global, regional, and national causes of child mortality in 2008: a systematic analysis. The lancet, 375(9730), 1969-1987. Bobak, M., & Leon, D. A. (1992). Air pollution and infant mortality in the Czech Republic, 1986-88. *The Lancet, 340*(8826), 1010-1014.

Bobak, M., & Leon, D. A. (1999). The Effect of Air Pollution on Infant Mortality Appears Specific for Respiratory Causes in the Postneonatal Period. *Epidemiology, 10*(6), 666-670.

Bock, R. D., & Moustaki, I. (2006). 15 Item Response Theory in a General Framework. *Handbook of statistics, 26, 469-513.*

Bodner, T. E. (2008). What improves with increased missing data imputations? *Structural Equation Modeling, 15*(4), 651-675.

Bond, R., & Mukherjee, N. (2002). Livelihood asset status tracking: an impact monitoring tool?. *Journal of International Development, 14*(6), 805-815.

Bonet, M., Smith, L. K., Pilkington, H., Draper, E. S., & Zeitlin, J. (2013). Neighbourhood deprivation and very preterm birth in an English and French cohort. *BMC pregnancy and childbirth, 13(1), 97.*

Boo, N., & Chor, C. (1994). Six year trend of neonatal septicaemia in a large Malaysian maternity hospital. *Journal of paediatrics and child health, 30*(1), 23-27.

Boy, E., Bruce, N., & Delgado, H. (2002). Birth weight and exposure to kitchen wood smoke during pregnancy in rural Guatemala. *Environmental health perspectives, 110*(1), 109-114.

Borjas, G. J., & Tienda, M. (1987). The economic consequences of immigration. *Science, 235*, 645-652.

Bosch, C., Hommann, K., Rubio, G. M., Sadoff, C., & Travers, L. (2001). Water, sanitation and poverty. *Draft chapter. Washington DC: World Bank*.

Boschi-Pinto, C., & Tomaskovic, L. (2006). Methods and assumptions for diarrhoea mortality estimates. *Available at: http://www.who.int/maternal_child_adolescent/documents/cherg_diarrhoea_mortality/en/*

Bosmans, K., Lauwers, L., Ooghe, E. (2009). A consistent multidimensional Pigou-Dalton transfer principle. *Journal of Economic Theory* 144, 1358-1371.

Bossert, T., Larrañaga, O., & Meir, F. R. (2000). Decentralization of health systems in Latin America Descentralización de los sistemas de salud en América Latina. *Revista Panamericana de Salud Pública, 8*(1-2), 84-92.

Boy, E., Bruce, N., & Delgado, H. (2002). Birth weight and exposure to kitchen wood smoke during pregnancy in rural Guatemala. *Environmental health perspectives, 110*(1), 109-114.

Browne, M. W. (1984). Asymptotically distribution-free methods for the analysis of covariance structures. *British Journal of Mathematical and Statistical Psychology, 37(1), 62-83.*

Bruce, N., Perez-Padilla, R., & Albalak, R. (2000). Indoor air pollution in developing countries: A major environmental and public health challenge. *World Health Organization. Bulletin of the World Health Organization, 78*(9), 1078-1092.

Bruch, E., & Atwell, J. (2015). Agent-based models in empirical social research. *Sociological methods & research, 44*(2), 186-221.

Buzaglo, J., Calzadilla, A. (2009). Towards a new consensus: poverty reduction strategies for Bolivia. *International Journal of Development Issues, 8(1), 18-39*

Buor, D. (2003). Mothers' education and childhood mortality in Ghana. *Health policy*, *64*(3), 297-309.

Bulle, N. (2016). A Method of Measuring Inequality Within a Selection Process. *Sociological Methods & Research*, *45*(1), 69-108.

Burström, B., Macassa, G., Öberg, L., Bernhardt, E., & Smedman, L. (2005). Equitable Child Health Interventions: The Impact of Improved Water and Sanitation on Inequalities in Child Mortality in Stockholm, 1878 to 1925. *American Journal of Public Health, 95*(2), 208-216.

Caldwell, J. (1979). Education as a Factor in Mortality Decline An Examination of Nigerian Data. *Population Studies, 33*(3), 395-413.

Cannadine, D. (1998). *Class in Britain*. Yale University Press.

Cárdenas, M. (2004). Cuentas Nacionales de Financiamiento y Gasto en Salud: *DIFID, Bolivia. Available at: www.phrplus.org/Pubs/Sir7s.pdf*

Carpenter, J., & Kenward, M. (2012). *Multiple imputation and its application*: John Wiley & Sons.

Castellanos, I.O.V. (2007). Extreme Poverty: Vulnerability and Coping Strategies Among Indigenous People in Rural Areas of Bolivia. *Cuvillier Verlag, Gottingen*

Casterline, J., Cooksey, E., & Ismail, A. (1989). Household income and child survival in Egypt. *Demography, 26*(1), 15-35.

Chakravorty, S. (1996). A measurement of spatial disparity: The case of income inequality. *Urban Studies, 33(9), 1671-1686.*

Chalasani, S. (2012). Understanding wealth- based inequalities in child health in India: A decomposition approach. *Social Science & Medicine, 75*(12), 2160-2169.

Chaplin, S. E. (1999). Cities, sewers and poverty: India's politics of sanitation. *Environment and Urbanization, 11*(1), 145-158.

Chaurey, A., Ranganathan, M., & Mohanty, P. (2004). Electricity access for geographically disadvantaged rural communities—technology and policy insights. *Energy policy, 32*(15), 1693-1705.

Cheema, J. R. (2014). Some general guidelines for choosing missing data handling methods in educational research. *Journal of Modern Applied Statistical Methods, 13*(2), 3.

Chou, C. P., Bentler, P. M., & Satorra, A. (1991). Scaled test statistics and robust standard errors for non-normal data in covariance structure analysis: a Monte Carlo study. *British Journal of Mathematical and Statistical Psychology, 44(2), 347-357.*

Chu, S. Y., Kim, S. Y., Lau, J., Schmid, C. H., Dietz, P. M., Callaghan, W. M., & Curtis, K. M. (2007). Maternal obesity and risk of stillbirth: a metaanalysis. *American journal of obstetrics and gynecology, 197(3), 223-228.*

CIHI. (1996). CIHI Country Health Profile: Bolivia. *Center for International Health Information. Available at: www.cihi.com.*

Clarke, K. A. (2005). The phantom menace: Omitted variable bias in econometric research. *Conflict management and peace science, 22(4), 341-352.*

Cliff, A., & Ord, J. K. (1973). Spatial autocorrelation. *Taylor & Francis; No. 04; QA278. 2, C5.*

Coa, R., Ochoa, L.H. (2009). Bolivia Encuesta Nacional de Demografía y Salud 2008. *Calverton, Maryland, USA: Ministerio de Salud y Deportes and Macro International. Available at: http://dhsprogram.com/pubs/pdf/FR228/FR228.pdf*

Coburn D. (2000) Income inequality, social cohesion, and the health status of populations: The role of neoliberalism. *Soc Sci Med 2000;58:41–56.*

Coburn, D. (2004). Beyond the income inequality hypothesis: class, neo-liberalism, and health inequalities. *Social Science and Medicine*, *58*(1), 41-56.

Cogswell, M. E., & Yip, R. (1995). The influence of fetal and maternal factors on the distribution of birthweight. In *Seminars in perinatology* (Vol. 19, No. 3, pp. 222-240).

Conde-Agudelo, A., Rosas-Bermúdez, A., & Kafury-Goeta, A. C. (2006). Birth spacing and risk of adverse perinatal outcomes: a meta-analysis. *Jama, 295(15), 1809-1823.*

Conley, D., & Strully, K. W. (2012). Birth weight, infant mortality, and race: Twin comparisons and genetic/environmental inputs. *Social Science & Medicine, 75(12), 2446-2454.*

Cornia, G. A. (2014). Falling inequality in Latin America: policy changes and lessons. *OUP Oxford*.

Costanza, R., Kubiszewski, I., Giovannini, E., Lovins, H., McGlade, J., Pickett, K. E., & Wilkinson, R. (2014). Development: Time to leave GDP behind. *Nature News*, *505*(7483), 283.

Crandall, M. S., & Weber, B. A. (2004). Local social and economic conditions, spatial concentrations of poverty, and poverty dynamics. *American Journal of Agricultural Economics, 86*(5), 1276-1281.

Crognier, E., Baali, A., Hilali, M. K., Villena, M., & Vargas, E. (2006). Preference for sons and sex ratio in two non-western societies. *American Journal of Human Biology*, *18*(3), 325-334.

Croissant, Y., & Millo, G. (2008). Panel data econometrics in R: The plm package. *Journal of Statistical Software, 27*(2), 1-43.

Curran, P. J., & Bauer, D. J. (2011). The disaggregation of within-person and between-person effects in longitudinal models of change. *Annual review of psychology, 62*, 583-619.

Daly, M. C., Duncan, G. J., Kaplan, G. A., & Lynch, J. W. (1998). Macro-to-micro links in the relation between income inequality and mortality. *The Milbank Quarterly, 76*(3), 315-339.

Das Gupta, M. (1990). Death clustering, mothers' education and the determinants of child mortality in rural Punjab, India. *Population studies*, *44*(3), 489-505.

Davanzo, J., Butz, W. P., & Habicht, J. P. (1983). How biological and behavioural influences on mortality in Malaysia vary during the first year of life. *Population Studies, 37*(3), 381-402.

Dawkins, C. J. (2007). Space and the measurement of income segregation. *Journal of Regional Science, 47(2), 255-272.*

de Graaf, J. P., Ravelli, A. C., de Haan, M. A., Steegers, E. A., & Bonsel, G. J. (2013). Living in deprived urban districts increases perinatal health inequalities. *The Journal of Maternal-Fetal & Neonatal Medicine, 26*(5), 473-481.

de Hilari, C., Condori, I., and Dearden, K.A. (2009). When is deliberate killing of young children justified? Indigenous interpretations of infanticide in Bolivia. *Social Science & Medicine 68.2: 352-361.*

de Sa, J., Bouttasing, N., Sampson, L., Perks, C., Osrin, D., & Prost, A. (2013). Identifying priorities to improve maternal and child nutrition among the Khmu ethnic group, Laos: a formative study. *Maternal & child nutrition, 9*(4), 452-466.

Decancq, K., Lugo, M.A. (2012). Inequality of Well-being: a Multidimensional Approach. *Economica* 79,721-746.

Deguen, S., Kihal, W., Jeanjean, M., Padilla, C., & Zmirou-Navier, D. (2016). Neighborhood deprivation and risk of congenital heart defects, neural tube defects and orofacial clefts: A systematic review and meta-analysis. *PloS one, 11*(10), e0159039.

Deolalikar, A. (2005). Attaining the Millennium Development Goals in India: Reducing Infant Mortality, Child Malnutrition, Gender Disparities and Hunger-Poverty and Increasing School Enrollment and Completion. *Journal of Economic Literature, 43*(4), 1140-1141.

Di Tommaso, M. L. (2006). Measuring the well being of children using a capability approach. An application to Indian data. *Available at: https://ideas.repec.org/p/wpc/wplist/wp05_06.html*

Divgi, D. (1979). Calculation of the tetrachoric correlation coefficient. *Psychometrika, 44*(2), 169-172.

Dong, G., & Harris, R. (2015). Spatial autoregressive models for geographically hierarchical data structures. *Geographical Analysis, 47(2), 173-191.*

Dorfman, R. (1979). A formula for the Gini coefficient. *The Review of Economics and Statistics, 146-149*.

Duncan, O. D., & Duncan, B. (1955). A methodological analysis of segregation indexes. *American Sociological Review, 20(2), 210-217.*

Edmond, K. M., Zandoh, C., Quigley, M. A., Amenga-Etego, S., Owusu-Agyei, S., & Kirkwood, B. R. (2006). Delayed breastfeeding initiation increases risk of neonatal mortality. *Pediatrics, 117(3), e380-e386.*

Edvinsson, S., & Janssens, A. (2012). Clustering of deaths in families: infant and child mortality in historical perspective. *Biodemography and Social Biology, 58*(2), 75.

Ehrenberg, H. M., Dierker, L., Milluzzi, C., & Mercer, B. M. (2003). Low maternal weight, failure to thrive in pregnancy, and adverse pregnancy outcomes. *American journal of obstetrics and gynecology, 189(6), 1726-1730.*

Eidelman, A. I., Schanler, R. J., Johnston, M., Landers, S., Noble, L., Szucs, K., & Viehmann, L. (2012). Breastfeeding and the use of human milk. *Pediatrics, 129(3), e827-e841.*

Eisenhower, D., Mathiowetz, N. A., & Morganstein, D. (1991). Recall error: Sources and bias reduction techniques. *Measurement errors in surveys*, 125-144.

Epstein, M., Bates, M., Arora, N., Balakrishnan, K., Jack, D., & Smith, K. (2013). Household fuels, low birth weight, and neonatal death in India: the separate impacts of biomass, kerosene, and coal. *International journal of hygiene and environmental health, 216*(5), 523-532.

Erikson, R., Goldthorpe, J.H. (1993). The Constant Flux. A Study of Class Mobility in Industrial Societies. Clarendon Press, Oxford.

Esrey, S. A., Potash, J. B., Roberts, L., & Shiff, C. (1991). Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. *Bulletin of the World Health Organization, 69*(5), 609.

Esrey, S. A. (1996). Water, waste, and well-being: a multicountry study. *American journal of epidemiology, 143*(6), 608-623.

Evans, G. W. (2004). The environment of childhood poverty. *American psychologist*, *59*(2), 77.

Falkingham, J., & Namazie, C. (2002). Measuring health and poverty: a review of approaches to identifying the poor. *London: DFID Health Systems Resource Centre, 7.*

Ferreira, F. H., & Lugo, M. A. (2013). Multidimensional poverty analysis: Looking for a middle ground. *The World Bank Research Observer*, *28*(2), 220-235.

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L., & Colford Jr, J. M. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. *The Lancet infectious diseases*, *5*(1), 42-52.

Field, D., Boyle, E., Draper, E., Evans, A., Johnson, S., Khan, K.,& Seaton, S. (2016). Towards reducing variations in infant mortality and morbidity: a population-based approach. *National Institute for Health Research, Programme grants for applied research. Vol.4, Issue 1.*

Filmer, D. (1997). *Child mortality and public spending on health : how much does money matter?* Washington, DC: Washington, DC : World Bank, Development Research Group.

Filmer, Deon & Kinnon, Scott (2012). Assessing asset indices. *Demography* 49.1: 359-392.

Fink, G., Günther, I., & Hill, K. (2011). The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986– 2007. *International Journal of Epidemiology*, *40*(5), 1196-1204.

Fiscella, Kevin, and Peter Franks. "Poverty or income inequality as predictor of mortality: longitudinal cohort study." *BMJ 314.7096 (1997): 1724.*

Flegg, A. T. (1982). Inequality of income, illiteracy and medical care as determinants of infant mortality in underdeveloped countries. *A Journal of Demography, 36*(3), 441-458.

Fleischman Foreit, K. G., & Mark, S. (2011). Comparing Alternative Measures of Poverty: Assets-Based Wealth Index vs. Expenditures-Based Poverty Score (pp. 1-21): *Chapel Hill, USA: Measure Evaluation & Carolina Population Center.*

Foster, J. E. (1998). Absolute versus Relative Poverty. The American Economic Review, 88(2), 335-341.

Fotso, J.-C., Ezeh, A. C., Madise, N. J., & Ciera, J. (2007). Progress towards the child mortality millennium development goal in urban sub-Saharan Africa: the dynamics of population growth, immunization, and access to clean water. *BMC Public Health*, *7*(1), 218.

Fox, J.-P. (2007). Multilevel IRT modeling in practice with the package mlirt. *Journal of Statistical Software, 20(5), 1-16.*

Freedman, D. A. (2012). On the so-called "Huber sandwich estimator" and "robust standard errors". *The American Statistician, 60(4), 299-302.*

Fuentes, F. (2015). How Bolivia grew its economy by rejecting neoliberalism. *Green Left Weekly* (1064), 19.

Fusco, A., & Dickes, P. (2008). The Rasch model and multidimensional poverty measurement. In *Quantitative approaches to multidimensional poverty measurement* (pp. 49-62). Palgrave Macmillan, London.

Gajdos, T., Weymark, J.A. (2005). Multidimensional generalized Gini indices. *Economic Theory* 26, 471-496.

Gastwirth, J. L. (1972). The estimation of the Lorenz curve and Gini index. *The review of economics and statistics, 306-316.*

Gelman, A., Carlin, J., Stern, H., & Rubin, D. (2013). Bayesian Data Analysis: *Chapman & Hall/CRC Texts in Statistical Science. London: Taylor & Francis.*

Gelman, A., & Rubin, D. B. (1992). Inference from iterative simulation using multiple sequences. *Statistical Science*, 457-472.

Gelman, A., Carlin, J. B., Stern, H. S., & Rubin, D. B. (2004). Bayesian data analysis. *Texts in statistical science series: Chapman & Hall/CRC, Boca Raton, FL.*

Genest, C., & McConway, K. J. (1990). Allocating the weights in the linear opinion pool. *Journal of Forecasting*, *9*(1), 53-73.

GeoBolivia. (2012). Establecimientos de salud de Bolivia, 2012. *Available at*: *http://geo.gob.bo/geonetwork/srv/spa/resources.get?id=1058&access=private&fname=*

GeoBolivia. (2013). Red vial fundamental de Bolivia 2012. *Available at*: *https://geo.gob.bo/geonetwork/srv/esp/catalog.search#/metadata/9c141353-e99b-44c9-b121-6f8fe75ac240*

GeoBolivia. (2017a). Capitales municipales de Bolivia (339 municipios), 2013. *Available at*: *https://geo.gob.bo/download/?w=fondos&l=CapitalesMunicipales*

GeoBolivia. (2017b). Mapa de amenaza de sequía meteorológica. *Available at*: *https://geo.gob.bo/geonetwork/srv/esp/catalog.search#/metadata/e304b259-8dcf-4886-b0f8-d0bcf99c02d0*

Ghosh, A. (1975). Concentration and growth of Indian industries, 1948-68. *The Journal of Industrial Economics*, 203-222.

Ghosn, W., Menvielle, G., Rican, S., & Rey, G. (2018). Associations of cause-specific mortality with area level deprivation and travel time to health care in France from 1990 to 2007, a multilevel analysis. *BMC public health, 18(1), 86.*

Gigler, B. S. (2009). Poverty, inequality and human development of indigenous peoples in Bolivia. *Georgetown University, Centre for Latin American Studies.*

Gingerich, D. W. (2009). Corruption and political decay: Evidence from Bolivia. *Quarterly Journal of Political Science, 4*(1), 1-34.

Goldstein, H., Browne, W., & Rasbash, J. (2002). Partitioning variation in multilevel models. *Understanding statistics: statistical issues in psychology, education, and the social sciences*, *1*(4), 223-231.

Goldstein, H., & Noden, P. (2003). Modelling social segregation. *Oxford Review of Education, 29*(2), 225-237.

Goldstein, H. (2011). Multilevel statistical models (Vol. 922): *John Wiley & Sons*.

Gonzales, G. (2007) Peruvian contributions to the study on human reproduction at high altitude: from the chronicles of the Spanish conquest to the present. *Respiratory physiology & neurobiology* 158.2-3: 172-179

Gonzalez, R., Requejo, J. H., Nien, J. K., Merialdi, M., Bustreo, F., & Betran, A. P. (2009). Tackling health inequities in Chile: maternal, newborn, infant, and child mortality between 1990 and 2004. *American Journal of Public Health, 99*(7), 1220.

Gordon, D. (2005). Indicators of poverty & hunger. In *Expert Group meeting on youth development indicators* (pp. 12-14). New York: United Nations Headquarters.

Graham, J. W., Olchowski, A. E., & Gilreath, T. D. (2007). How many imputations are really needed? Some practical clarifications of multiple imputation theory. *Prevention science, 8*(3), 206-213.

Gravelle, H. (1998). How much of the relation between population mortality and unequal distribution of income is a statistical artefact? *BMJ, 316*(7128), 382.

Gray-Molina, G., Jimenez, W. L., & de Rada, E. P. (2002). Social exclusion: residential segregation in Bolivian cities. *Inter-American Development Bank; Research Network working papers; R-440.*

Greene, R. (1991). Poverty concentration measures and the urban underclass. *Economic Geography, 67*(3), 240-252.

Griffiths P, Madise N, Whitworth A, Matthews Z (2004) A tale of two continents: a multilevel comparison of the determinants of child nutritional status from selected African and Indian regions. *Health Place 10: 183–199*

Grootaert, C., & Narayan, D. (2004). Local institutions, poverty and household welfare in Bolivia. *World Development, 32*(7), 1179-1198.

Grosh, M. E., & Glewwe, P. (1998). Data watch: the World Bank's living standards measurement study household surveys. *Journal of Economic Perspectives*, *12*(1), 187-196.

Grosse, M., Harttgen, K., & Klasen, S. (2005). Measuring Pro- Poor Growth with Non- Income Indicators. *IDEAS Working Paper Series from RePEc*.

Grund, S., Lüdtke, O., & Robitzsch, A. (2016). Multiple imputation of multilevel missing data: An introduction to the R Package pan. *SAGE Open, 6*(4), 2158244016668220.

Grundy, E., & Holt, G. (2001). The socioeconomic status of older adults: How should we measure it in studies of health inequalities?. *Journal of Epidemiology & Community Health*, *55*(12), 895-904.

Guildea, Z., Fone, D., Dunstan, F., Sibert, J., & Cartlidge, P. (2001). Social deprivation and the causes of stillbirth and infant mortality. *Archives of Disease in Childhood, 84*(4), 307-310.

Gulliford, M., Figueroa-Munoz, J., Morgan, M., Hughes, D., Gibson, B., Beech, R., & Hudson, M. (2002). What "does access to health care" mean? *Journal of health services research & policy, 7*(3), 186.

Günther, I., & Klasen, S. (2009). Measuring chronic non-income poverty. *Poverty dynamics: Interdisciplinary perspectives*, 77-101.

Günther, I., & Fink, G. Water, sanitation and children's health: evidence from 172 DHS surveys. *World Bank Policy Research Working Paper Series, Vol (2010).*

Gwatkin, D. R., Guillot, M., & Heuveline, P. (1999). The burden of disease among the global poor. The Lancet, 354(9178), 586-589.

Hagenaars, A. J. (2017). The definition and measurement of poverty. In *Economic Inequality and Poverty: International Perspectives* (pp. 148-170). Routledge.

Hammond, J. L. (2011). Indigenous Community Justice in the Bolivian Constitution of 2009. *Human Rights Quarterly, 33*(3), 649-681.

Harris, R. (2017) Measuring the scales of segregation: Looking at the residential separation of White British and other schoolchildren in England using a multilevel index of dissimilarity. *Transactions of the Institute of British Geographers, 42(3), 432-444.*

Harris, R., & Owen, D. (2017). Implementing a Multilevel Index of Dissimilarity in R with a case study of the changing scales of residential ethnic segregation in England and Wales. *Environment and Planning B: Urban Analytics and City Science, 2399808317748328.*

Havard, J. (1995). World summit on social development. *The Lancet*, *345*(8946), 335-336.

Henderson V. (2003). The urbanization process and economic growth: The so-what question. *Journal of Economic growth* 8.1: 47-71

Hill, K., Bicego, G., & Mahy, M. (2001). Childhood mortality in Kenya: An examination of trends and determinants in the late 1980s to mid 1990s. *Johns Hopkins Population Center Working Paper*.

Hill, K., You, D., Inoue, M., & Oestergaard, M. Z. (2012). Child mortality estimation: accelerated progress in reducing global child mortality, 1990–2010. *PLoS Med, 9*(8), e1001303.

Hobcraft, J. N., McDonald, J. W., & Rutstein, S. O. (1984). Socio-economic factors in infant and child mortality: a cross-national comparison. *Population studies, 38(2), 193-223*.

Hoch, I. (1958). Simultaneous equation bias in the context of the Cobb-Douglas production function. *Econometrica: Journal of the Econometric Society*, 566-578.

Hong, R., Ahn, P. Y., Wieringa, F., Rathavy, T., Gauthier, L., Hong, R., & Poirot, E. (2017). The unfinished health agenda: Neonatal mortality in Cambodia. *PloS one, 12(3), e0173763*.

Howard, R. (2009). Education reform, indigenous politics, and decolonisation in the Bolivia of Evo Morales. *International Journal of Educational Development, 29*(6), 583-593.

Howe, L. D., Hargreaves, J. R., & Huttly, S. R. (2008). Issues in the construction of wealth indices for the measurement of socio-economic position in low-income countries. *Emerging themes in epidemiology, 5*(1), 1.

Hutchens, R. (2001) Numerical measures of segregation: desirable properties and their implications. *Mathematical social sciences, 42(1), 13-29.*

Huy, T. Q., Long, N. H., Hoa, D. P., Byass, P., & Eriksson, B. (2003). Validity and completeness of death reporting and registration in a rural district of Vietnam. *Scandinavian journal of public health, 31*(62_suppl), 12-18.

Iceland, J., Weinberg, D., & Hughes, L. (2014). The residential segregation of detailed Hispanic and Asian groups in the United States: 1980-2010. *Demographic Research*, *31*, 593.

INE (2002). Censo Nacional de Población y Vivienda 2001: Resultados nacionales (Vol. 4 ed.): *INE Instutito Nacional de Estadística.*

Jaadla, H., & Puur, A. (2016). The impact of water supply and sanitation on infant mortality: Individual-level evidence from Tartu, Estonia, 1897–1900. *Population Studies, 70*(2), 163-179.

Jain, A. K. (1985). Determinants of Regional Variations in Infant Mortality in Rural India. *Population Studies, 39*(3), 407-424.

James, F. J. (1986). A new generalized "exposure-based" segregation index: Demonstration in Denver and Houston. *Sociological Methods & Research*, *14*(3), 301-316.

Jencks, C., & Mayer, S. E. (1990). The social consequences of growing up in a poor neighborhood. *Inner-city poverty in the United States*, *111*, 186.

Jensen, J., Krishnan, V., Spittal, M., & Sathiyandra, S. (2003). New Zealand living standards: their measurement and variation, with an application to policy. *Social Policy Journal of New Zealand*, 72-97.

Johannesson, M. (2004). Absolute Income, Relative Income, Income Inequality, and Mortality. *The Journal of Human Resources, 39(1), 228-247.*

Johnston, R., Forrest, J., Jones, K., & Manley, D. (2016). The scale of segregation: Ancestral groups in Sydney, 2011. *Urban Geography, 37(7), 985-1008.*

Jolliffe, I. T. (1986). Principal Component Analysis and Factor Analysis. *Principal component analysis* (pp. 115-128): Springer.

Jones, K., Johnston, R., Forrest, J., Charlton, C., & Manley, D. (2018a). Ethnic and class residential segregation: exploring their intersection–a multilevel analysis of ancestry and occupational class in Sydney. *Urban Studies, 55(6), 1163-1184.*

Jones, K., Manley, D., Johnston, R., & Owen, D. (2018b). Modelling residential segregation as unevenness and clustering: a multilevel modelling approach incorporating spatial dependence and tackling the MAUP. *Environment and Planning B: Urban Analytics and City Science, 45(6), 1122-1141.*

Jones, K., Johnston, R., Manley, D., Owen, D., & Charlton, C. (2015). Ethnic residential segregation: A multilevel, multigroup, multiscale approach exemplified by London in 2011. *Demography, 52(6), 1995-2019.*

Jones, K., & Subramanian, S.V. (2013). Developing multilevel models for analysing contextuality, heterogeneity and change using MLwiN Volume 2. *Bristol: Centre for Multilevel Modelling, University of Bristol. Available at: https://www.researchgate.net/publication/260772180_Developing_multilevel_models_for_analysing_contextuality_heterogeneity_and_change_using_MLwiN_Volume_2.*

Jöreskog, K. G., & Goldberger, A. S. (1975). Estimation of a model with multiple indicators and multiple causes of a single latent variable. *Journal of the American Statistical Association, 70(351a), 631-639.*

Jöreskog, K. G., & Sörbom, D. (1999). LISREL 8.30 and PRELIS 2.30. Chicago: Scientific Software International.

Kamal, S. M. M. (2012). Maternal Education as a Determinant of Neonatal Mortality in Bangladesh. *Journal of Health Management*, *14*(3), 269-281.

Karlsen, S., Say, L., Souza, J.-P., Hogue, C. J., Calles, D. L., Gülmezoglu, A. M., & Raine, R. (2011). The relationship between maternal education and mortality among women giving birth in health care institutions: analysis of the cross sectional WHO Global Survey on Maternal and Perinatal Health. *BMC Public Health, 11*(1), 1.

Kawachi, I., & Berkman, L. F. (2003). Neighborhoods and health. *Oxford University Press*.

Kawachi, I., Subramanian, S. V., & Almeida-Filho, N. (2002). A glossary for health inequalities. *J Epidemiol Community Health, 56*(9), 647.

Kayode, G. A., Ansah, E., Agyepong, I. A., Amoakoh-Coleman, M., Grobbee, D. E., & Klipstein-Grobusch, K. (2014). Individual and community determinants of neonatal mortality in Ghana: a multilevel analysis. *BMC pregnancy and childbirth, 14(1), 165.*

Kerber, K. J., de Graft-Johnson, J. E., Bhutta, Z. A., Okong, P., Starrs, A., & Lawn, J. E. (2007). Continuum of care for maternal, newborn, and child health: from slogan to service delivery. *The Lancet, 370(9595), 1358-1369.*

Kessler, C., & Stroosnijder, L. (2006). Land degradation assessment by farmers in Bolivian mountain valleys. *Land Degradation & Development, 17*(3), 235-248.

Khan, A. E., Ireson, A., Kovats, S., Mojumder, S. K., Khusru, A., Rahman, A., & Vineis, P. (2011). Drinking water salinity and maternal health in coastal Bangladesh: implications of climate change. *Environmental health perspectives, 119*(9), 1328.

Kim, J., & Jargowsky, P. A. (2009). The Gini Coefficient and segregation on a continuous variable. *In Y. Flückiger, S. F. Reardon & J. Silber (Eds.), Occupational and Residential Segregation (Vol. 17, pp. 57-70): Emerald Group Publishing Limited.*

Kim, T. K., & Lane, S. R. (2013). Government Health Expenditure and Public Health Outcomes: A Comparative Study among 17 Countries and Implications for US Health Care Reform: *American International Journal of Contemporary Research: Vol. 3 No. 9*

Kim, D., & Saada, A. (2013). The social determinants of infant mortality and birth outcomes in Western developed nations: a cross-country systematic review. *International journal of environmental research and public health, 10(6), 2296-2335.*

King, E. M., & Hill, M. A. (1993). Women's education in developing countries : barriers, benefits, and policies. *Baltimore: Baltimore : Published for the World Bank by the John Hopkins University Press*.

Kish, L. (1954). Differentiation in metropolitan areas. *American Sociological Review, 19(4), 388-398.*

Kitts, J. (1996). *The health gap : beyond pregnancy and reproduction*. Ottawa: Ottawa : International Development Research Centre.

Klasen, S. (2000). Measuring Poverty and Deprivation in South Africa. *Review of Income and Wealth* 46, 33-58.

Klein, H. S. (2003). *A concise history of Bolivia*. Cambridge: Cambridge : Cambridge University Press.

Kline, P. (2014). *An easy guide to factor analysis*. Routledge.

Knack S. & Keefer P. (1997). "Does social capital have an economic payoff? A cross-country investigation." *The Quarterly journal of economics* 112.4: 1251-1288

Knippenberg, R., Lawn, J. E., Darmstadt, G. L., Begkoyian, G., Fogstad, H., Walelign, N., & Lancet Neonatal Survival Steering Team. (2005). Systematic scaling up of neonatal care in countries. The Lancet, 365(9464), 1087-1098.Knott, M., & Albanese, M. T. (1992). Conditional distributions of a latent variable and scoring for binary data. *Brazilian Journal of Probability and Statistics*, 171-188.

Koblinsky, M. A. (2003). *Reducing maternal mortality : learning from Bolivia, China, Egypt, Honduras, Indonesia, Jamaica, and Zimbabwe*. Washington, DC: Washington, DC : World Bank.

Kohl, B. (2010). Bolivia under Morales A Work in Progress. *Latin American Perspectives, 37*(3), 107-122.

Kolenikov, S., & Angeles, G. (2004). The use of discrete data in PCA: theory, simulations, and applications to socioeconomic indices. *Chapel Hill: Carolina Population Center, University of North Carolina*, 1-59.

Kost, K., & Amin, S. (1992). Reproductive and socioeconomic determinants of child survival: Confounded, interactive, and age-dependent effects. *Social biology, 39*(1-2), 139-150.

Kozuki, N., Lee, A. C., Silveira, M. F., Victora, C. G., Adair, L., Humphrey, J., & Katz, J. (2013). The associations of birth intervals with small-for-gestational-age, preterm, and neonatal and infant mortality: a meta-analysis. *BMC public health, 13(3), S3*.

Kramer, M. S., Seguin, L., Lydon, J., & Goulet, L. (2000). Socio-economic disparities in pregnancy outcome: why do the poor fare so poorly? *Paediatric and perinatal epidemiology, 14*(3), 194-210.

Kravdal, Ø. (2006). A simulation-based assessment of the bias produced when using averages from small DHS clusters as contextual variables in multilevel models. *Demographic Research*, *15*, 1-20.

Krishnakumar, J. (2008). *Multidimensional measures of poverty and well-being based on latent variable models Quantitative approaches to multidimensional poverty measurement (pp. 118-134): Springer*.

Kuklys, W. (2005). The measurement of functionings achievement: Structural Equation Models as an alternative. *Amartya Sen's Capability Approach: Theoretical insights and empirical applications, 31-57.*

Lagendijk, E., Assere, A., Derens, E., & Carpentier, B. (2008). Domestic refrigeration practices with emphasis on hygiene: analysis of a survey and consumer recommendations. *Journal of Food Protection, 71*(9), 1898-1904.

Lalou, R., & LeGrand, T. K. (1997). Child mortality in the urban and rural Sahel. *Population an English Selection*, 147-168.

Langeheine, R., Pannekoek, J., & Van de Pol, F. (1996). Bootstrapping goodness-of-fit measures in categorical data analysis. *Sociological Methods & Research, 24*(4), 492-516.

Larrea, C., & Kawachi, I. (2005). Does economic inequality affect child malnutrition? The case of Ecuador. *Social Science & Medicine, 60*(1), 165-178.

Lawn, J. E., Cousens, S., & Zupan, J. (2005). 4 million neonatal deaths: When? Where? Why? *The Lancet, 365*(9462), 891-900.

Lawn, J. E., Kerber, K., Enweronu-Laryea, C., & Massee Bateman, O. (2009). Newborn survival in low resource settings—are we delivering? *BJOG: An International Journal of Obstetrics & Gynaecology, 116*(s1), 49-59.

Lawn, J. E., Kinney, M., Lee, A. C. C., Chopra, M., Donnay, F., Paul, V. K., Darmstadt, G. L. (2009). Reducing intrapartum- related deaths and disability: Can the health system deliver? *International Journal of Gynecology and Obstetrics, 107,* S123-S142.

Lawrence, P. R., Meigh, J., & Sullivan, C. (2002). *The water poverty index: an international comparison*. Keele, Straffordshire, UK: Department of Economics, Keele University.

Leckie, G., Pillinger, R., Jones, K., & Goldstein, H. (2012). Multilevel Modeling of Social Segregation. *Journal of Educational and Behavioral Statistics, 37(1), 3-30.*

Leckie, G. (2015). Three-level multilevel models–concepts. *LEMMA VLE Module 11, 1–47.*

Leckie, G., & Goldstein, H. (2015). A multilevel modelling approach to measuring changing patterns of ethnic composition and segregation among London secondary schools, 2001–2010. *Journal of the Royal Statistical Society: Series A (Statistics in Society), 178(2), 405-424.*

Ledo, C., & Soria, R. (2011). Sistema de salud de Bolivia. The health system of Bolivia. *Salud Pública de Mexico, 53*, s109-s119.

Lee, J. H., & Huber Jr, J. (2011). Multiple imputation with large proportions of missing data: How much is too much? *Paper presented at the United Kingdom Stata Users' Group Meetings 2011.*

Lee, A. C., Cousens, S., Darmstadt, G. L., Blencowe, H., Pattinson, R., Moran, N. F. & Lawn, J. E. (2011). Care during labor and birth for the prevention of intrapartum-related neonatal deaths: a systematic review and Delphi estimation of mortality effect. *BMC public health*, *11*(3), S10.

Lelli, S. (2001). Factor Analysis vs. Fuzzy Sets theory: Assessing the influence of different techniques on Sen's functioning approach: *Kath. Univ., Department Economie, Center for Economic Studies*.

Lelli, S. (2005). Using functionings to estimate equivalence scales. *Review of Income and Wealth* 51, 255-284.

Lhila, A., & Simon, K. I. (2010). Relative deprivation and child health in the USA. *Social Science and Medicine, 71*(4), 777-785.

Lichter, D. T., Parisi, D., & Taquino, M. C. (2012). The geography of exclusion: Race, segregation, and concentrated poverty. *Social Problems, 59*(3), 364-388.

Lieberson, S., Peach, C., Robinson, V., Smith, S. (1981). An asymmetrical approach to segregation. *In Peach, C., Robinson, V., & Smith, S. (Eds.) Ethnic segregation in cities, pp. 61-82. Taylor & Francis*

Loehlin, J. C. (2004). Latent variable models: An introduction to factor, path, and structural equation analysis. *Psychology Press*.

Lozano, R., Wang, H., Foreman, K. J., Rajaratnam, J. K., Naghavi, M., Marcus, J. R., Dwyer-Lindgren, L., Lofgren, K.T., Phillips, D., Atkinson, C. & Lopez, A. D. (2011). Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis. *The Lancet, 378*(9797), 1139-1165.

Lunn, D. J., Thomas, A., Best, N., & Spiegelhalter, D. (2000). WinBUGS-a Bayesian modelling framework: concepts, structure, and extensibility. *Statistics and computing, 10*(4), 325-337.

Luo, Z.-C., Kierans, W. J., Wilkins, R., Liston, R. M., Mohamed, J., & Kramer, M. S. (2004). Disparities in Birth Outcomes by Neighborhood Income: Temporal Trends in Rural and Urban Areas, British Columbia. *Epidemiology, 15*(6), 679-686.

Lynch, J., Smith, G. D., Hillemeier, M., Shaw, M., Raghunathan, T., & Kaplan, G. (2001). Income inequality, the psychosocial environment, and health: comparisons of wealthy nations. *The Lancet, 358*(9277), 194-200.

Maantay J. (2002). Mapping environmental injustices: pitfalls and potential of geographic information systems in assessing environmental health and equity. Environ Health Perspect;110 (suppl 2):161–71

Maasoumi, E. (1986). The Measurement and Decomposition of Multi-Dimensional Inequality. *Econometrica* 54, 991-997.

Maasoumi, E., & Nicklesburg, G. (1988). Multidimensional measure of well-being and an analysis of inequality in the Michigan data. *Journal of Businnes and Economical Statistics, 6(3), 327-334.*

Macinko, J., Guanais, F. C., & De Souza, M. D. F. M. (2006). Evaluation of the impact of the Family Health Program on infant mortality in Brazil, 1990–2002. *Journal of Epidemiology & Community Health, 60*(1), 13-19.

Macinko, J. A., Shi, L., & Starfield, B. (2004). Wage inequality, the health system, and infant mortality in wealthy industrialized countries, 1970–1996. *Social science & medicine, 58*(2), 279-292.

Mahajan, S. D., Singh, S., Shah, P., Gupta, N., & Kochupillai, N. (2004). Effect of maternal malnutrition and anemia on the endocrine regulation of fetal growth. *Endocrine research, 30*(2), 189-203.

Mahy, M., & Zaba, B. (2003). Measuring child mortality in AIDS-affected countries. *Paper presented at the Workshop on HIV/AIDS and Adult Mortality in Developing Countries. New York, United States of America.*

Makdissi, P., & Wodon, Q. (2006). Fuel poverty and access to electricity: comparing households when they differ in needs. *Applied Economics, 38*(9), 1071-1078.

Målqvist, M. (2011). Neonatal mortality: an invisible and marginalised trauma. *Global health action, 4*.

Manassaram, D. M., Backer, L. C., & Moll, D. M. (2007). A review of nitrates in drinking water: maternal exposure and adverse reproductive and developmental outcomes. *Ciencia & saude coletiva, 12*, 153-163.

Manley, D., Johnston, R., Jones, K., & Owen, D. (2015). Macro-, meso-and microscale segregation: Modeling changing ethnic residential patterns in Auckland, New Zealand, 2001–2013. *Annals of the Association of American Geographers, 105(5), 951-967.*

Marmot, M. (2005). Social determinants of health inequalities. *The Lancet, 365*(9464), 1099-1104.

Marmot, M. G., Stansfeld, S., Patel, C., North, F., Head, J., White, I., & Smith, G. D. (1991). Health inequalities among British civil servants: the Whitehall II study (pp. 1387-1393): *The Lancet* 337.8754.

Marof, T. (1965). *Breve biografía de Víctor Paz Estenssoro: vida y trasfondo de la política boliviana*: Editorial Juventud.

Martines, J., Paul, V. K., Bhutta, Z. A., Koblinsky, M., Soucat, A., Walker, N., Costello, A. (2005). Neonatal survival: a call for action. *The Lancet, 365*(9465), 1189-1197.

Mason, A. (2005). Demographic transition and demographic dividends in developed and developing countries. *Paper presented at the United Nations expert group meeting on social and economic implications of changing population age structures.*

Massey, D. S., & Denton, N. A. (1988). The dimensions of residential segregation. *Social Forces, 67*(2), 281-315.

Massey, D. S., White, M. J., & Phua, V. C. (1996). The dimensions of segregation revisited. *Sociological Methods & Research, 25*(2), 172-206.

Matthews, S. A., & Parker, D. M. (2013). Progress in spatial demography. *Demographic Research, 28, 271-312.*

Mayer, S. E., & Sarin, A. (2005). Some mechanisms linking economic inequality and infant mortality. *Social Science & Medicine, 60*(3), 439-455.

McIntire, D. D., Bloom, S. L., Casey, B. M., & Leveno, K. J. (1999). Birth weight in relation to morbidity and mortality among newborn infants. *New England journal of medicine, 340(16), 1234-1238.*

McKenzie, D. J. (2005). Measuring inequality with asset indicators. *Journal of Population Economics, 18*(2), 229-260.

McKinnon, B., Harper, S., Kaufman, J. S., & Bergevin, Y. (2014). Socioeconomic inequality in neonatal mortality in countries of low and middle income: a multicountry analysis. *The Lancet Global Health, 2*(3), e165-e173.

Merschrod, K. (1981) The index of dissimilarity as a measure of inequality. *Quality and Quantity, 15(4), 403-411.*

Mertens, T., Fernando, M., Cousens, S. N., Kirkwood, B. R., Marshall, T., & Feachem, R. (1990). Childhood diarrhoea in Sri Lanka: a case-control study of the impact of improved water sources. *Trop Med Parasitol, 41*(1), 98-104.

Mesike, C., & Mojekwu, J. (2012). Environmental Determinants of Child Mortality in Nigeria. *Journal of Sustainable Development, 5*(1), 65-75.

Michels, A. (2011). Migration and inheritance practices in the Bolivian Altiplano. *Working paper/World Institute for Development Economics Research*.

Milanovic, B. (2016). *Increasing capital income share and its effect on personal income inequality* (No. 663). LIS Working Paper Series.

Miller, D. L., & Paxson, C. (2006). Relative income, race, and mortality. *Journal of health economics, 25(5), 979-1003.*

Molyneux, M., & Thomson, M. (2011). Cash transfers, gender equity and women's empowerment in Peru, Ecuador and Bolivia. *Gender and Development, 19*(2), 195-212.

Montagu, D., Yamey, G., Visconti, A., Harding, A., & Yoong, J. (2011). Where do poor women in developing countries give birth? A multi-country analysis of demographic and health survey data. PloS one, 6(2), e17155.

Moore, S. (2006). Peripherality, income inequality, and life expectancy: revisiting the income inequality hypothesis. International Journal of Epidemiology, 35(3), 623-632.

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

Morrill, R.L. (1991). On the measure of spatial segregation. *Geography research forum 11:25-36.*

Murray, C. J., Laakso, T., Shibuya, K., Hill, K., & Lopez, A. D. (2007). Can we achieve Millennium Development Goal 4? New analysis of country trends and forecasts of under-5 mortality to 2015. *The Lancet, 370*(9592), 1040-1054.

Muthén, B. (1997). Latent variable modeling of longitudinal and multilevel data. *Sociological methodology, 27*(1), 453-480.

Muthén, B., Muthén, L. K., & Asparouhov, T. (2010). Bayesian Analysis Using Mplus. *Available at: www.statmodel.com/download/Bayes3.pdf*

Muthén, L., & Muthén, B. (2010). Mplus software (version 6). *Los Angeles, CA: Muthén & Muthén*.

Nandy, S., Irving, M., Gordon, D., & Subramanian, S. (2005). Poverty, child undernutrition and morbidity: new evidence from India. *World Health Organization. Bulletin of the World Health Organization, 83*(3), 210-216.

Naeye, R. L., Burt, L. S., Wright, D. L., Blanc, W. A., & Tatter, D. (1971). Neonatal mortality, the male disadvantage. *Pediatrics, 48(6), 902-906.*

Napierala, J., & Denton, N. (2017) Measuring residential segregation with the ACS: How the margin of error affects the dissimilarity index. *Demography, 54(1), 285-309.*

Navarro, V., & Shi, L. (2001). The political context of social inequalities and health. *International Journal of Health Services, 31(1), 1-21.*

Neal, S. E. (2009). Neonatal Mortality in Developing Countries: an analysis of trends and determinants. *University of Southampton, School of Social Sciences, PhD thesis.*

Neal, S. E., & Falkingham, J. (2014). Neonatal Death and National Income in Developing Countries: Will Economic Growth Reduce Deaths in the First Month of Life? *International Journal of Population Research, 2014*.

Nolan, B., & Whelan, C. T. (2010). Using non-monetary deprivation indicators to analyze poverty and social exclusion: Lessons from Europe?. *Journal of Policy Analysis and Management, 29*(2), 305-325.

Norheim, O. F., Jha, P., Admasu, K., Godal, T., Hum, R. J., Kruk, M. E., Sepúlveda, J. (2015). Avoiding 40% of the premature deaths in each country, 2010–30: review of national mortality trends to help quantify the UN Sustainable Development Goal for health. *The Lancet, 385*(9964), 239-252.

Nowatzki, N. R. (2012). Wealth inequality and health: a political economy perspective. *International Journal of Health Services, 42*(3), 403-424.

O'Campo, P., Burke, J. G., Culhane, J., Elo, I. T., Eyster, J., Holzman, C., Laraia, B. A. (2007). Neighborhood deprivation and preterm birth among non-Hispanic Black and White women in eight geographic areas in the United States. *American journal of epidemiology, 167*(2), 155-163.

O'Sullivan, K. C., Howden-Chapman, P. L., & Fougere, G. (2011). Making the connection: The relationship between fuel poverty, electricity disconnection, and prepayment metering. *Energy Policy, 39*(2), 733-741.

Ochoa, L.H., Gutiérrez, M., Raggers, H. (1994). Encuesta Nacional de Demografía y Salud. *Macro International Inc. Calverton, Maryland, USA.*

Ogunlesi, T. A., & Abdul, A. R. (2015). Maternal knowledge and care. Seeking behaviors for newborn jaundice in Sagamu, Southwest Nigeria. *Nigerian journal of clinical practice, 18*(1), 33-40.

Olson, M. E., Diekema, D., Elliott, B. A., & Renier, C. M. (2010). Impact of income and income inequality on infant health outcomes in the United States. *Pediatrics, 126*(6), 1165-1173.

OPS (2002). Análisis de las reformas del sector salud en los países de la región Andina (2da. Edición ed.). *Washington D.C.: Organización Panamericana de la Salud.*

Otis, K. E., & Brett, J. A. (2008). Barriers to hospital births: why do many Bolivian women give birth at home? *Revista Panamericana de Salud Pública, 24*(1), 46-53.

Owen, D. (2015). Measuring residential segregation in England and Wales: A model-based approach *(Doctoral dissertation, University of Bristol).*

Padilla, C., Kihal-Talantikit, W., Vieira, V., & Deguen, S. (2016). City-specific spatiotemporal infant and neonatal mortality clusters: Links with socioeconomic and air pollution spatial patterns in France. *International journal of environmental research and public health, 13(6), 624.*

Pamuk, E. R., Fuchs, R., & Lutz, W. (2011). Comparing Relative Effects of Education and Economic Resources on Infant Mortality in Developing Countries. *Population and Development Review, 37*(4), 637-664.

Parker, J. D., Schoendorf, K. C., & Kiely, J. L. (1994). Associations between measures of socioeconomic status and low birth weight, small for gestational age, and premature delivery in the United States. *Annals of epidemiology, 4*(4), 271-278.

Patel, M. (1980). Effects of the health service and environmental factors on infant mortality: the case of Sri Lanka. *Journal of Epidemiology & Community Health, 34*(2), 76-82.

Pathirana, J., Muñoz, F. M., Abbing-Karahagopian, V., Bhat, N., Harris, T., Kapoor, A., Pande, S. L. (2016). Neonatal death: Case definition & guidelines for data collection, analysis, and presentation of immunization safety data. *Vaccine, 34*(49), 6027-6037.

Pattenden, S., Dolk, H., & Vrijheid, M. (1999). Inequalities in low birth weight: parental social class, area deprivation, and "lone mother" status. *Journal of Epidemiology & Community Health, 53*(6), 355-358.

Paulson, S., Gisbert, M.E., Quitón, M. (1996). Case studies of two womens health projects in Bolivia. *USAid working papers; Document No. 127864; Available at: https://www.popline.org/node/306664*

Pebley, A., & Stupp, P. (1987). Reproductive patterns and child mortality in Guatemala. *Demography, 24*(1), 43-60.

Pelling, J. (2009). Lessons in respect: a new midwifery training programme that teaches the importance of cultural respect is bringing hope to thousands of women in Bolivia. *Midwives Magazine*, 32-34.

Perez-Heydrich, C., Warren, J. L., Burgert, C. R., & Emch, M. (2013). Guidelines on the use of DHS GPS data. *ICF International*.

Perry, H. B., Shanklin, D. S., & Schroeder, D. G. (2003). Impact of a community-based comprehensive primary healthcare programme on infant and child mortality in Bolivia. *Journal of health, population, and nutrition, 21*(4), 383.

Pesenti, N., Quatto, P., & Ripamonti, E. (2017). Bootstrap confidence intervals for biodiversity measures based on Gini index and entropy. *Quality & Quantity, 51*(2), 847-858.

Peters, D. H., Garg, A., Bloom, G., Walker, D. G., Brieger, W. R., & Hafizur Rahman, M. (2008). Poverty and access to health care in developing countries. *Annals of the New York Academy of Sciences, 1136*(1), 161-171.

Piachaud, D. (1987). Problems in the definition and measurement of poverty. *Journal of Social Policy, 16*, 147-164.

Pickett, K. E., & Wilkinson, R. G. (2007). Child wellbeing and income inequality in rich societies: ecological cross sectional study. *BMJ, 335*(7629), 1080.

Pickett, K. E., & Wilkinson, R. G. (2015). Income inequality and health: a causal review. *Social science & medicine, 128, 316-326.*

Pitchforth, E., van Teijlingen, E., Graham, W., Dixon-Woods, M., & Chowdhury, M. (2006). Getting women to hospital is not enough: a qualitative study of access to emergency obstetric care in Bangladesh. *Qual Saf Health Care, 15*(3), 214.

Pnud (2010). Informe sobre Desarrollo Humano 2009. *Relaciones Internacionales, 0*(14).

Poma, M. (2008). *Evo Morales : de cocalero a presidente de Bolivia* (1 ed. ed.). Barcelona : Flor del Viento Ediciones.

Pooley, B., Ramirez, M., & De Hilari, C. (2008). Bolivia's Health Reform: a response to improve access to obstetric care. *Studies in HSO&P*, pp. 199-222.

Population Reference Bureau (2013). 2013 World Population Data Sheet. *Available at: www.prb.org/pdf13/2013-population-data-sheet_eng.pdf*

Pratto, F., Sidanius, J., Stallworth, L. M., & Malle, B. F. (1994). Social dominance orientation: A personality variable predicting social and political attitudes. *Journal of personality and social psychology, 67*(4), 741.

Preston, S. H., & Haines, M. R. (2014). *Fatal years: Child mortality in late nineteenth-century America*: Princeton University Press.

Pritchett, L., & Summers, L. (1996). Wealthier is healthier. *The Journal of Human Resources, 31*(4), 841-868.

Proietti, E., Röösli, M., Frey, U., & Latzin, P. (2013). Air pollution during pregnancy and neonatal outcome: a review. *Journal of aerosol medicine and pulmonary drug delivery, 26*(1), 9-23.

Prudhomme, R. m. (1994). *On the dangers of decentralization*. Washington, D.C.: Washington, D.C.: Transportation, Water & Urban Development Department, World Bank.

Psacharopoulos, G. (1993). Ethnicity, education, and earnings in Bolivia and Guatemala. *Comparative Education Review, 37*(1), 9-20.

Punch, S. (2004). The impact of primary education on school-to-work transitions for young people in rural Bolivia. *Youth & Society, 36*(2), 163-182.

R Core Team. (2014). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria. 2013: ISBN 3-900051-07-0.*

Rabe-Hesketh, S., & Skrondal, A. (2004). Generalized latent variable modeling: Multilevel, longitudinal, and structural equation models. *Chapman and Hall/CRC. Royall, R. M. (1986). Model robust confidence intervals using maximum likelihood estimators. International Statistical Review/Revue Internationale de Statistique, 221-226*.

Rahman, S., Salameh, K., Bener, A., & El Ansari, W. (2010). Socioeconomic associations of improved maternal, neonatal, and perinatal survival in Qatar. *International Journal of Women's Health, 2*, 311-318.

Rajaratnam, J. K., Marcus, J. R., Flaxman, A. D., Wang, H., Levin-Rector, A., Dwyer, L., ... & Murray, C. J. (2010). Neonatal, postneonatal, childhood, and under-5 mortality for 187 countries, 1970–2010: a systematic analysis of progress towards Millennium Development Goal 4. *The Lancet, 375(9730), 1988-2008*.

Ramírez Hita, S. (2014). Intercultural aspects of the health system reform in Bolivia. *Revista peruana de medicina experimental y salud pública, 31*(4), 762.

Ransom, M. R. (2000). Sampling distributions of segregation indexes. *Sociological Methods & Research, 28*(4), 454-475.

Razzaque, A., Streatfield, P. K., & Gwatkin, D. R. (2007). Does health intervention improve socioeconomic inequalities of neonatal, infant and child mortality? Evidence from Matlab, Bangladesh. *International Journal for Equity in Health, 6*, 4-4.

Reagan, P. B., Salsberry, P. J., & Olsen, R. J. (2007). Does the measure of economic disadvantage matter? Exploring the effect of individual and relative deprivation on intrauterine growth restriction. *Social Science and Medicine, 64*(10), 2016-2029.

Rip, M. R., Keen, C. S., & Woods, D. L. (1987). Intra- urban variations of neonatal and post- neonatal mortality in a developing city. *Social Science & Medicine, 25*(8), 889-894.

Robusto, C. C. (1957). The cosine-haversine formula. *The American Mathematical Monthly, 64*(1), 38-40.

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). *Journal of statistical software, 48*(2), 1-36.

Rubin, D. B. (1987). Procedures with nonignorable nonresponse. *Multiple Imputation for Nonresponse in Surveys*, 202-243.

Runciman, W. G. (1966). Relative deprivation and social justice : a study of attitudes to social inequality in twentieth-century England. *London: Routledge & Kegan Paul*.

Rutstein, S. (2000). Factors associated with trends in infants and child mortality in developing countries during the 1990s. *World Health Organization. Bulletin of the World Health Organization, 78*(10), 1256-1270.

Rutstein, S., & Johnson, K. (2004). The DHS wealth index. *ORC Macro, Measure DHS*.

Rutstein, S. (2008). The DHS Wealth Index: Approaches for rural and urban areas. *DHS working papers; USAid No.60. Available at: https://www.popline.org/node/209748*

Sachs, J. D., & Warner, A. M. (1997). Sources of slow growth in African economies. *Journal of African economies, 6*(3), 335-376.

Sachs, J. D. (2012). From millennium development goals to sustainable development goals. *The Lancet, 379*(9832), 2206-2211.

Saigal, S., & Doyle, L. W. (2008). An overview of mortality and sequelae of preterm birth from infancy to adulthood. *The Lancet, 371*(9608), 261-269.

Salmond, C., & Crampton, P. (2012). Measuring socioeconomic position in New Zealand. *Journal of primary health care, 4*(4), 271-280.

Sakamoto, Y., Ishiguro, M., & Kitagawa, G. (1986). Akaike information criterion statistics. *Dordrecht, The Netherlands: D. Reidel.*

Sarkadi, A., Kristiansson, R., Oberklaid, F., & Bremberg, S. (2008). Fathers' involvement and children's developmental outcomes: a systematic review of longitudinal studies. *Acta paediatrica, 97(2), 153-158.*

Savitz, D. A., Whelan, E. A., & Kleckner, R. C. (1989). Effect of parent's occupational exposures on risk of stillbirth, preterm delivery, and small-for gestational- age infants. *American journal of epidemiology, 129*(6), 1201-1218.

Say, L., & Raine, R. (2007). A systematic review of inequalities in the use of maternal health care in developing countries: examining the scale of the problem and the importance of context. *Bulletin of the World Health Organization, 85*(10), 812-819.

Scalone, F., Agati, P., Angeli, A., & Donno, A. (2017). Exploring unobserved heterogeneity in perinatal and neonatal mortality risks: The case of an Italian sharecropping community, 1900–39. *Population Studies, 71*(1), 23-41.

Schafer, J. L. (2001). Multiple imputation with PAN. *Available at: www.psycnet.apa.org/record/2001-01077-012.*

Schafer, J. L., & Graham, J. W. (2002). Missing data: our view of the state of the art. *Psychological methods, 7*(2), 147.

Schavelzon, S. (2010). A abertura e o estado pluralista como busca de solução constitucional ao problema das "Duas Bolivías" (pp. 80-97): *Cadernos PROLAM/USP* 16.

Schoen, R., & Nau, C. (2008). A behaviorally-based approach to measuring inequality. *Demographic Research, 19*, 1727-1748.

Schroeder, K. (2007). Economic globalization and Bolivia's regional divide. *Journal of Latin American Geography, 6*(2), 99-120.

Scott, S., & Duncan, C. J. (2000). Interacting effects of nutrition and social class differentials on fertility and infant mortality in a pre-industrial population. *Population Studies, 54*(1), 71-87.

Sen, A. (1989). Development as Capability Expansion. *Journal of Development Planning*, (19).

Sen, A. (2000). *Development as freedom* (1st Anchor Books ed. ed.). New York: New York : Anchor Books.

Sexton K., & Anderson Y. (1993). Equity in environmental health: research issues and needs. Toxicol Ind Health;9:679–977

Shesko, E. (2015). Mobilizing Manpower for War: Toward a New History of Bolivian Chaco Conflict, 1932–1935. *Vol. 95, pp. 299.*

Shiono, P. H., & Behrman, R. E. (1995). Low birth weight: Analysis and recommendations. *The Future of Children*, 4-18.

Shrimpton, R. (2003). Preventing low birthweight and reduction of child mortality. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *97*(1), 39-42.

Silva, R. (2012). Child mortality estimation: consistency of under-five mortality rate estimates using full birth histories and summary birth histories. *PLoS Med*, *9*(8), e1001296.

Silver, H. (1994). Social exclusion and social solidarity: three paradigms. *Int'l Lab. Rev., 133*, 531.

Simmons, R. G., & Rosenberg, M. (1971). Functions of Children's Perceptions of the Stratification System. *American Sociological Review, 36*(2), 235-249.

Singh, A., Vainchtein, D., & Weiss, H. (2009). Schelling's segregation model: parameters, scaling, and aggregation. *Demographic Research*, *21*, 341-366.

Singh, P. K., Rai, R. K., Alagarajan, M., & Singh, L. (2012). Determinants of maternity care services utilization among married adolescents in rural India. *PloS one, 7(2), e31666.*

Skiles, M. P., Burgert, C. R., Curtis, S. L., & Spencer, J. (2013). Geographically linking population and facility surveys: methodological considerations. *Population health metrics*, *11*(1), 14.

Skrondal, A. (2004). *Generalized latent variable modeling : multilevel, longitudinal, and structural equation models*. Boca Raton: Boca Raton : Chapman & Hall/CRC.

Smith, K. R., McCracken, J. P., Weber, M. W., Hubbard, A., Jenny, A., Thompson, L. M., . . . Bruce, N. (2011). Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial. *The Lancet, 378*(9804), 1717-1726.

Snijders, T. A. B., & Bosker, R. J. (2012). Multilevel analysis: an introduction to basic and advanced multilevel modeling. *International Encyclopedia of Statistical Science*. Springer Berlin Heidelberg, 2011. 879-882..

Solar, O., & Irwin, A. (2007). A conceptual framework for action on the social determinants of health: discussion paper for the Commission on Social Determinants of Health. Geneva: World Health Organization.

Sparks, P. J., Sparks, C. S., & Campbell, J. J. (2013). An application of Bayesian spatial statistical methods to the study of racial and poverty segregation and infant mortality rates in the US. *GeoJournal, 78*(2), 389-405.

Spilerman, S. (2000). Wealth and stratification processes. *Annual Review of Sociology*, 497-524.

Sprigg, C. A., Stride, C. B., Wall, T. D., Holman, D. J., & Smith, P. R. (2007). Work characteristics, musculoskeletal disorders, and the mediating role of psychological strain: a study of call center employees. *Journal of Applied Psychology, 92(5), 1456.*

Stafford, M., & Marmot, M. (2003). Neighbourhood deprivation and health: does it affect us all equally?. *International journal of epidemiology, 32(3), 357-366.*

StataCorp. (2013). Structural Equation Modelling Reference Manual, Release 13. *Stata Journal, College Station, TX: StataCorp LP*.

Stares, S. R. (2008). Latent trait and latent class models in survey analysis: Case studies in public perceptions of biotechnology (*Doctoral dissertation, London School of Economics and Political Science (United Kingdom)).*

Steele, F. (2008). Module 5: Introduction to multilevel modelling concepts. Lemma Course - Centre for multilevel modelling. *Available at: http://www.bristol.ac.uk/cmm/learning/online-course/*

Steele, F., Clarke, P., Leckie, G., Allan, J., & Johnston, D. (2016). Multilevel structural equation models for longitudinal data where predictors are measured more frequently than outcomes: an application to the effects of stress on the cognitive function of nurses. *Journal of the Royal Statistical Society, Series A*, 180 (1), 263-283.

Stiglitz, J. E. (2009). GDP fetishism. *The Economists' Voice, 6*(8).

Stiglitz, J.E., Sen, A.K., Fitoussi, J.P. (2009). Report by the Commission on the Measurement of Economic Performance and Social Progress, www.stiglitz-sen-fitoussi.fr.

Stiglitz, J. (2013). The Price of Inequality. *New Perspectives Quarterly, 30*(1), 52-53.

Stockwell, E. G., Swanson, D. A., & Wicks, J. W. (1988). Economic status differences in infant mortality by cause of death. *Public Health Reports, 103*(2), 135.

Stretesky, P. B., Schuck, A. M., & Hogan, M. J. (2004). Space matters: An analysis of poverty, poverty clustering, and violent crime. *Justice Quarterly, 21*(4), 817-841.

Sui, B., Feng, G. F., & Chang, C. P. (2018). The pioneer evidence of contagious corruption. *Quality & Quantity, 52*(2), 945-968.

Sullivan, C., & Meigh, J. (2003). Considering the Water Poverty Index in the context of poverty alleviation. *Water policy, 5*(5-6), 513-528.

Szwarcwald, C.L., Andrade, C.L.T.D., Bastos, F.I. (2002). Income inequality, residential poverty clustering and infant mortality: a study in Rio de Janeiro, Brazil. *Soc. Sci. Med. 55(12), 2083–2092*

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). Using multivariate statistics (Vol. 5). *Boston, MA: Pearson*.

Tacke, T., & Waldmann, R. J. (2013). Infant mortality, relative income and public policy. *Applied Economics, 45*(22), 3240-3254.

Tandon, A. (2005). Attaining millennium development goals in health: isn't economic growth enough? ERD Policy Brief No. 35, Asian Development Bank, Manila

Taskaya, S., & Demirkiran, M. (2017). Determinants of infant mortality in last two decades: a bibliometric analysis. *International Journal Of Community Medicine And Public Health, 3(4), 776-780*.

Thaddeus, S., & Maine, D. (1994). Too far to walk: maternal mortality in context. *Social science & medicine, 38(8), 1091-1110.*

Theil, H., & Theil, H. (1972). Statistical decomposition analysis; with applications in the social and administrative sciences. *London North-Holland197337 p; HA33 T4***.**

Thomas, D. (1990). Intra- Household Resource Allocation: An Inferential Approach. *The Journal of Human Resources, 25*(4), 635-664.

Thompson, B. (2004). Exploratory and confirmatory factor analysis: Understanding concepts and applications: *American Psychological Association*.

Titaley, C. R., Dibley, M. J., Agho, K., Roberts, C. L., & Hall, J. (2008). Determinants of neonatal mortality in Indonesia. *BMC Public Health, 8*, 232-232.

Townsend, P. (1979). Poverty in the United Kingdom: a survey of household resources and standards of living. *University of California Press*.

Tsai, S.-S.; Chen, C.-C.; Hsieh, H.-J.; Chang, C.-C.; Yang, C.-Y. Air pollution and postneonatal mortality in a tropical city: Kaohsiung, Taiwan. *Inhal. Toxicol. 2006*

Turley, R. N. L. (2002). Is relative deprivation beneficial? The effects of richer and poorer neighbors on children's outcomes. *Journal of Community Psychology, 30*(6), 671-686.

UDAPE, & UNICEF (2006). Bolivia: Evaluación de Impacto de los Seguros de Maternidad y Niñez en Bolivia 1989-2003. *La Paz: UDAPE y UNICEF.*

UNICEF, WHO, World Bank, & UN-DESA Population Division (2015). Levels and trend of child mortality 2015. *WHO Press, 20 Avenue Appia, 1211 Geneva 27, Switzerland: WHO Library.*

UNICEF. (2018) The neonatal period is the most vulnerable time for a child. *Available at: https://data.unicef.org/topic/child-survival/neonatal-mortality/*

United Nations (2005). Gender equality, women's empowerment essential to vision of world free from want, fear, Third Committee told, as discussion of women's issues begins. *M2 Presswire*.

United Nations Fund for Population Agency, Unicef, World Bank, & World Health Organization (1999). *Reduction of maternal mortality : a joint WHO/UNFPA/UNICEF/World Bank statement*. Geneva: Geneva : World Health Organization.

United Nations (2015). The Millennium Development Goals Report 2015. New York: United Nations.

US Aid (2012). Sampling and household listing manual. *DHS Toolkit of methodology for the MEASURE DHS Phase III project*.

Vadez, V., Reyes-García, V., Godoy, R. A., Apaza, V. L., Byron, E., Huanca, T., . . . Wilkie, D. (2004). Does integration to the market threaten agricultural diversity? Panel and cross-sectional data from a horticultural-foraging society in the Bolivian Amazon. *Human Ecology*, 635-646.

Van de Poel, E., Donnell, O., & Doorslaer, E. (2009). What explains the rural- urban gap in infant mortality: Household or community characteristics? *Demography, 46*(4), 827-850.

Van der Linden, W. J., & Hambleton, R. K. (1997). Item response theory: Brief history, common models, and extensions Handbook of modern item response theory (pp. 1-28): *Springer*.

Vandemoortele, J. (2000). Absorbing social shocks, protecting children and reducing poverty : the role of basic social services. *UNICEF staff working papers. Evaluation, policy and planning series. Number EPP-00-001.*

Vandemoortele, M. (2014). Measuring Household Wealth with Latent Trait Modelling: An Application to Malawian DHS Data. *An International and Interdisciplinary Journal for Quality-of-Life Measurement, 118(2), 877-891*.

Vandebroek, I. (2004). Use of medicinal plants and pharmaceuticals by indigenous communities in the Bolivian Andes and Amazon. *Bulletin of the World Health Organization, 82*(4), 243-250.

Verhoeven, M., Gupta, S., & Tiongson, E. (1999). Does Higher Government Spending Buy Better Results in Education and Health Care? *IDEAS Working Paper Series from RePEc*.

Victora, C. G., Huttly, S. R., Fuchs, S. C., & Olinto, M. T. (1997). The role of conceptual frameworks in epidemiological analysis: a hierarchical approach. *International journal of epidemiology, 26(1), 224-227.*

Vos, A. A., Posthumus, A. G., Bonsel, G. J., Steegers, E. A., & Denktaş, S. (2014). Deprived neighborhoods and adverse perinatal outcome: a systematic review and meta-analysis. *Acta Obstetricia et Gynecologica Scandinavica*, *93*(8), 727-740

Vuletin, G. J. (2008). *Measuring the informal economy in Latin America and the Caribbean* (No. 8-102). International Monetary Fund.

Wagle, U. (2005). Multidimensional Poverty Measurement with Economic Well-being, Capability, and Social Inclusion: A Case from Kathmandu, Nepal. *Journal of Human Development, 6(3), 301-328.*

Wagstaff, A. (2002). Inequality aversion, health inequalities and health achievement. Journal of Health Economics, 21(4), 627-641.

Wagstaff, A. and Watanabe N. (2003). What Difference Does the Choice of SES Make in Health Inequality Measurement. *Health Economics* 12: 885-90.

Waldmann, R. J. (1992). Income distribution and infant mortality. *The Quarterly Journal of Economics*, *107*(4), 1283-1302.

Wall, S. N., Lee, A. C. C., Niermeyer, S., English, M., Keenan, W. J., Carlo, W., . . . Lawn, J. E. (2009). Neonatal resuscitation in low- resource settings: What, who, and how to overcome challenges to scale up? *International Journal of Gynecology and Obstetrics, 107,* S47-S64.

Washington-Allen, R., Ramsey, R., Norton, B., & West, N. (1998). Change detection of the effect of severe drought on subsistence agropastoral communities on the Bolivian Altiplano. *International Journal of Remote Sensing, 19*(7), 1319-1333.

Webber, J. (2011). From rebellion to reform in Bolivia: Class struggle, indigenous liberation, and the politics of Evo Morales: *Haymarket Books*.

Weich, S., Lewis, G., & Jenkins, S. P. (2002). Income inequality and self rated health in Britain. *Journal of Epidemiology & Community Health, 56*(6), 436-441.

Weisbrot, M., & Sandoval, L. (2008). The distribution of Bolivia's most important natural resources and the autonomy conflicts. *Center for Economic and Policy Research*, 2.

Whelan, C. T., Layte, R., Maître, B., & Nolan, B. (2001). Income, deprivation, and economic strain. An analysis of the European community household panel. European sociological review, 17(4), 357-372.

Whelan, C. T., & Maître, B. (2007). Measuring material deprivation with EU-SILC: Lessons from the Irish survey. *European Societies, 9(2), 147-173.*

Whitehead, L. (1976). Banzer's Bolivia [political and economic conditions under General Hugo Banzer, president since Aug., 1971]. *Current History, 70,* 61-64.

Wiggins, S., Schejtman, A., & Gray, G. (2006). Bolivia case study: an interpretative summary. *Research programme consortium on improving institutions for pro-poor growth. Working paper series n. 1.*

Wight, R. G., Aneshensel, C. S., D., M.-M., Botticello, A. L., Cummings, J. R., Karlamangla, A. S., & Seeman, T. E. (2006). Urban neighborhood context, educational attainment, and cognitive function among older adults. *American journal of epidemiology, 163.12* 1071-1078.

Wilkinson, R. G. (1994). The epidemiological transition: from material scarcity to social disadvantage? *Daedalus,* 61-77.

Wilkinson, R. G. (1997). Socioeconomic Determinants of Health: Health Inequalities: Relative or Absolute Material Standards? *BMJ: British Medical Journal, 314*(7080), 591-595.

Wilkinson, R. G., & Pickett, K. E. (2006). Income inequality and population health: A review and explanation of the evidence. *Social science & medicine, 62*(7), 1768-1784.

Willis, J. R., Kumar, V., Mohanty, S., Singh, P., Singh, V., Baqui, A. H., & Darmstadt, G. L. (2009). Gender differences in perception and care-seeking for illness of newborns in rural Uttar Pradesh, India. *Journal of health, population, and nutrition, 27(1), 62.*

Winikoff, B. (1983). The effects of birth spacing on child and maternal health. *Studies in family planning, 231-245.*

Wong, D. W. (1993). Spatial indices of segregation. *Urban studies, 30(3), 559-572.*

Woodruff, T.J.; Darrow, L.A.; Parker, J.D. Air pollution and postneonatal infant mortality in the United States, 1999–2002. Environ. Health Perspect. 2008, 116, 110–115

Woods, R. (2003). Urban- Rural Mortality Differentials: An Unresolved Debate. *Population and Development Review, 29*(1), 29-46.

Wooldridge, J. M. (2010). Econometric Analysis of Cross Section and Panel Data. *The MIT Press, Cambridge, MA, 2nd edition.*

World Bank. (2000). World Bank confronts poverty in Eastern Europe And Former Soviet Union; Making Transition Work for Everyone: Poverty and Inequality in Europe and Central Asia. M2 Presswire.

World Bank. (2004). *Health sector reform in Bolivia : a decentralization case study*. Washington, D.C.: Washington, D.C. : World Bank.

World Bank. (2005). Bolivia Country Economic Memorandum. Policies to Improve Growth and Employment.: Report No. 32233-BO, July 20, 2005, Washington DC.

World Bank (2014). Bolivian data. *Available at: http://data.worldbank.org/country/bolivia*

World Bank. (2015). Urbanization trends in Bolivia, opportunities and challenges. *Global Program Unit, May 2015*.

World Bank (2017). World Bank databases. *Available at: https://data.worldbank.org/indicator/*

World Health Organization (2006a). Meeting the MDG drinking water and sanitation target: the urban and rural challenge of the decade. Avenue Appia 20, 121 Geneva. Available at: www.who.int

World Health Organization (2006b). Body mass index – BMI. *Available at: http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi*

World Health Organization. (2009). Global health risks: mortality and burden of disease attributable to selected major risks. *World Health Organization*.

World Health Organization & UNICEF (2014). Progress on drinking? water and sanitation: 2014 Update. *World Health Organization Available at: http://www.who.int/water_sanitation_health/publications/jmp_report-2012/en/*

World Health Organization. (2016). Fact sheet number 292. *http://www.who.int/mediacentre/factsheets/fs292/en*.

World Health Organization (2017). Infant mortality rate database. *Available at: https://www.who.int/gho/countries/en/*

Yasmin, S., Osrin, D., Paul, E., & Costello, A. (2001). Neonatal mortality of low-birth-weight infants in Bangladesh. *Bulletin of the World Health Organization*, *79*, 608-614.

Zhang, J. J., & Smith, K. R. (2007). Household air pollution from coal and biomass fuels in China: measurements, health impacts, and interventions. *Environmental health perspectives*, *115*(6), 848.

Zhang, Z. (2016). Multiple imputation for time series data with Amelia package. *Annals of translational medicine, 4*(3).

Zoloth, B. S. (1976). Alternative measures of school segregation. *Land Economics, 52(3), 278-298.*

Zoomers, A. (2006). Pro-Indigenous Reforms in Bolivia: Is there an Andean Way to Escape Poverty? *Development and Change, 37*(5), 1023-1046.