

DO POVERTY AND ECONOMIC INEQUALITY MATTER FOR NEONATAL MORTALITY? INTERNATIONAL COMPARISON OF MACRO-LEVEL DETERMINISTIC PATTERNS OF EARLY-AGE MORTALITY

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1. INTRODUCTION

The reduction of early-age mortality, and especially its neonatal component (first 28 days of life), represents a major challenge for health systems worldwide. Although a decrease in neonatal mortality rates (NMRs) has been observed over the last decades, the pace of decline has been slower than that of infant or child mortality. As a result, the proportion of under-five mortality occurring within the neonatal period has been gradually higher in the world, from 37% of the total in 1990 to 44% in 2013 (UNICEF *et al.*, 2015). Figure 1 shows that this pattern has occurred in every area of the world, except in the Western Pacific (World Health Organization, 2016).

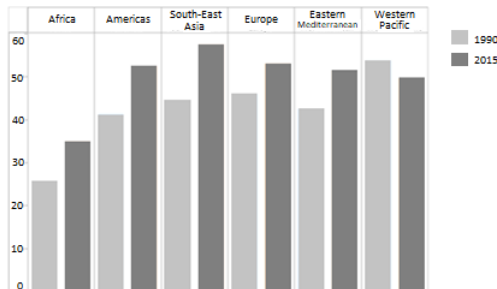


Figure 1 – Neonatal deaths as percentage of under-five mortality.

According to UNICEF (2018) data, West and Central African countries present the highest NMR in the world in 2015, with an estimate of 31.4 deaths per 1,000 live

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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, 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) and one of the fastest pace of reduction in the world (56.2% between 1990 and 2015).

The reduction of infant mortality plays a fundamental role in triggering the demographic transition, and determines variation in the patterns of the transition across countries (Pozzi and Fariñas, 2015). For instance, sub-Saharan Africa had a delayed and slower mortality transition in comparison with other areas, and still have higher levels of infant mortality (Garenne and Gakusi, 2006). This pattern is also due to political crises, civil wars, and the effect of the HIV/AIDS epidemics (*ibid*).

Neonatal mortality has been labelled as 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 of misreporting 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 occurring at home, particularly in low- and middle-income countries (McClure *et al.*, 2006); NMRs might be therefore biased in official statistics (Målqvist, 2011). A recent call for action has helped to bring international attention on neonatal mortality (Lawn *et al.*, 2005; Martines *et al.*, 2005; Darmstadt *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 Goals 4 (Lozano *et al.*, 2011). While the socioeconomic determinants of infant and child mortality have been extensively analysed in the literature, neonatal mortality requires a more detailed investigation (Neal, 2009). 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; Preston and Haines, 2014; Pritchett and Summers, 1993). However, few 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 with neonatal mortality (Lawn *et al.*, 2005; Neal, 2009; Neal and Falkingham, 2014), but evidence is still insufficient. 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). Moreover, there is some evidence that not only the absolute level of wealth, but also its distribution may affect mortality outcomes (Wagstaff, 2002; Mayer and Sarin, 2005; Wilkinson and Pickett, 2006). 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); economic development might have played a stronger role in tackling post-neonatal mortality (Flegg, 1982), explaining

the relative stagnation of NMRs.

This paper investigates the association between a set of national-level socioeconomic determinants and early-age mortality rates using country-level panel data. Two models including the same covariates are fitted to predict NMRs and post-neonatal mortality rates (PNMRs). The focus is on the potential different patterns of association of poverty and economic inequality with mortality between the neonatal and post-neonatal periods. Aiming to study the research question: “Do poverty and economic inequality have different patterns of association with neonatal mortality and post-neonatal mortality, at the macro level?”, this paper builds on 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 period at the macro level.

In the final part of this study, non-monetary measures of deprivation are used instead of the national gross domestic product, in order to evaluate their association with neonatal and post-neonatal mortality. A recent trend in the study of poverty is to use non-monetary measures of deprivation (Grosse *et al.*, 2005). Assessing deprivation from a broader perspective and looking beyond the sole concepts of income or consumption expenditure, these indicators complement income-based measures by describing the lack of basic needs such as resources or services (Vandemoortele, 2000), since income cannot fully describe a household’s living environment (Piachaud, 1987) and can have strong variation over time (Nowatzki, 2012). The national proportions of households with access to electricity, improved water sources and improved sanitation facilities are used as measures of deprivation, thus defining deprivation as a lack of basic needs related to the housing environment.

2. SOCIOECONOMIC DETERMINANTS OF NEONATAL MORTALITY

2.1. Poverty

Poverty can be identified as an underlying cause of many neonatal deaths, due to its effect on several risk factors during the antenatal and neonatal period (Wagstaff, 2002). Unfavourable economic conditions are found to be positively associated with risk factors, acting through environmental aspects (Jain, 1985; Rutstein, 2000), nutritional deprivation both in mothers and children (United Nations Fund for Population *et al.*, 1999), maternal education (Neal, 2009), and reduced access to health care (Lawn *et al.*, 2005). There is evidence in the literature of a stronger association between poverty and mortality in the post-neonatal period, than in the neonatal period. This pattern was identified following analyses of the association between GDP per capita and neonatal and post-neonatal mortality, in two cross-sectional studies in low- and middle-income countries (Neal, 2009; Neal and Falkingham, 2014). Other studies found a correlation between household income and under-five mortality, but not with neonatal mortality in Guatemala (Pebley and Stupp, 1987), in Malaysia (DaVanzo *et al.*, 1983), and in Egypt (Casterline *et al.*, 1989).

2.2. *Income inequality*

Few studies have assessed the association between neonatal mortality and economic inequality, and neonatal mortality is rarely compared to mortality occurring later in life. Among the studies finding a positive relationship, Mayer and Sarin (2005) found income inequality 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 effect of income inequality on neonatal mortality in a micro-level study in Rio de Janeiro.

2.3. *Alternative measures of deprivation*

An interpretation of poverty in monetary terms dominates in the literature. However, 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, 2014).

Another perspective on poverty involves the use of non-income indicators in directly measuring the functioning of households (Grosse *et al.*, 2005). Deprivation can therefore be considered as a lack of basic needs, such as resources or services (Vandemoortele, 2000). In general, a reduction in poverty leads to a rise in household living standards, with a commensurate improvement in access to electricity, clean water and adequate sanitation, directly impacting child and adult health (Nandy *et al.*, 2005). At the individual level, a well-known non-monetary measure is the Demographic and Health Survey wealth index, whose association with child health outcomes is found to be significant in several articles (Hill *et al.*, 2001; Mesike and Mojekwu, 2012; Pamuk *et al.*, 2011). The Oxford Multidimensional Poverty Index (Alkire and Santos, 2014) is another indicator belonging to this stream of literature.

The final part of this paper explores the association between early-age mortality and the non-income dimension of poverty. Three measures of deprivation have been considered: access to electricity, clean water, and improved sanitation. These variables have been considered the most significant and measurable factors that can explain the latent concept of household deprivation. They have been preferred to composite measures of deprivation, such as the Demographic and Health Survey wealth index, which allows ranking of households within countries, but which is not suitable for international comparisons, being an indicator of wealth only in a specific country-year combination (McKenzie, 2005). The chosen variables allow identification of extremely deprived households, lacking basic needs for a minimal living standard, and allow comparisons over time and space. This pragmatic approach to deprivation measurement has a practical use in social policies aiming to identify and fight extreme deprivation.

- Access to electricity: The first measure of deprivation is the national proportion of households connected 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 to 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 dark hours, and of motive power.
- Access to clean water: The quality of water supply is associated with early-age mortality, due to exposure to water-borne diseases, particularly those causing diarrhoea (Esrey *et al.*, 1991). Moreover, clean water is related to improved personal and food preparation hygiene, and to a reduced risk of infections (Mertens *et al.*, 1990). Access to clean water is found to be significantly associated with early-age mortality (Macinko *et al.*, 2006; Victora *et al.*, 1997).
- Access to improved sanitation: The third measure of deprivation is the percentage of a population with access to improved sanitation². The WHO considers inadequate sanitation as 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; Rutstein, 2000).

2.4. Other socioeconomic variables

In addition to the two determinants of interest (poverty and economic inequality), also female education, expenditures on health and place of residence have been highlighted in the literature as factors affecting early-age mortality. These variables are those available at the macro level, among the determinants of neonatal mortality included in Titaley *et al.* (2008) and Målqvist (2011) theoretical frameworks.

The relationship between maternal education and neonatal mortality is found to be strongly negative, in high-income countries (Arntzen *et al.*, 2007), as well as in low- and middle-income countries (Kamal, 2012). Possible explanations for the link between

² Improved sanitation includes sewage and septic systems, while open pit and surface water are considered unimproved sanitation (Fink *et al.*, 2011).

maternal education and neonatal mortality include higher knowledge regarding complications, adequate access to health services, quality of feeding and household sanitation (Neal, 2009). 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).

The relationship between public expenditure on a health system and children's health outcomes is not clear: while some studies reported a positive correlation (Bhalotra, 2006; Kim and Lane, 2013; Verhoeven *et al.*, 1999), other analyses have found no significant association (Filmer, 1999; Deolalikar, 2005). Factors associated with lower neonatal mortality include adequate equipment (Boo and Chor, 1994), a suitable environment, availability of transport (Lawn *et al.*, 2009) and delivery at a health facility (Wall *et al.*, 2009).

Finally, urban-rural mortality differentials in early-age mortality exist in low- and middle-income countries (Van de Poel *et al.*, 2009). Rural areas are associated with a lower probability of individuals seeking health care, due to lower access to health services in comparison with urban areas (Andersen, 2002), and cultural issues (Lalou and LeGrand, 1997; Say and Raine, 2007; Kitts and Roberts, 1996). Rural areas are likely to lack infrastructures (Andersen, 2002), and to have limited access to electricity and clean water supply (Van de Poel *et al.*, 2009) exposing rural populations to endemic diseases.

3. DATA AND MEASURES

Here, country-level panel data are analysed in order to assess the association between early-age mortality and the socioeconomic determinants described above. The data are from the World Bank (2015) database. Countries were selected if their NMR in 2015 was higher than the threshold of 12 per 1000 live births, specified by Sustainable Development Goal 3.2 (Norheim *et al.*, 2015). For each of the selected 79 countries, data from 2000, 2005, 2010 and 2015 were included. The list of selected countries is presented in Appendix A. The logarithmic transformation of the outcome variables *NMR* and *PNMR* were carried out to obtain an approximately normally-distributed variable (the Shapiro test produced p -value < 0.01 for *NMR*, and p -value=0.13 for $\log(\text{NMR})$; p -values < 0.01 and equal to 0.02 for, respectively, *PNMR* and $\log(\text{PNMR})$). Table 1 shows the list of the 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. This trend is due to the ongoing demographic transition (Mason, 2007), as well as to the fact that early-age mortality has been specifically targeted by Millennium Development Goal 4, fostering policy initiatives and investments specifically targeting under-five mortality (Murray *et al.*, 2007; Rajaratnam *et al.*, 2010). Table 2 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 strategy is discussed in the next chapter.

TABLE 1
Variables and description.

Variable	Label	Description
First outcome	<i>NMR</i>	Neonatal mortality rates by five-year periods preceding the survey, excluding month of interview from analysis
Second outcome	<i>PNMR</i>	Post-neonatal mortality rates by five-year periods preceding the survey
Poverty	<i>GDPpc</i>	The gross domestic product per capita, based on purchasing power parity, converted to international dollars. The logarithmic transformation of GDP has been included in the models.
Income inequality	<i>Gini</i>	The gross domestic product per capita, based on purchasing power parity, converted to international dollars. The logarithmic transformation of GDP has been included in the models.
Access to electricity	<i>Electricity</i>	Percentage of population with access to electricity.
Access to clean water	<i>Water</i>	Percentage of population using an improved drinking water source, including piped water, boreholes or tube wells, protected dug wells, protected springs, and packaged or delivered water.
Access to improved sanitation	<i>Sanitation</i>	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.
Female education	<i>Education</i>	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	<i>Health expenditure</i>	Percentage of national GDP dedicated to public and private health expenditures, covering health services, family planning activities, nutrition activities, and emergency aid. It does not include provision of water and sanitation.
Rurality	<i>Rural</i>	Percentage of rural population, as defined by national statistics offices.

TABLE 2
Descriptive statistics and proportion of missing for country-year observations.

Variable	Median	Min	Max	Proportion missing
<i>NMR</i>	28.5	12.8	61.3	0
<i>PNMR</i>	24.8	2.6	92.0	0
<i>GDPpc</i>	2,470.5	419.5	33,777.3	0
<i>Gini</i>	42.4	16.6	63.0	83.4
<i>Education</i>	68.5	12.7	124.7	40.3
<i>Health Expenditure</i>	5.2	0.9	21.9	27.5
<i>Rural</i>	63.3	0.0	91.8	0.3
<i>Electricity</i>	42.7	0.1	100.0	25.9
<i>Water</i>	75.6	28.9	100.0	3.4
<i>Sanitation</i>	38.8	6.6	100.0	5.9

4. STATISTICAL METHODS

4.1. Multilevel multiple imputation for missing data

As seen in Table 2, the World Bank database has missing data for some variables; the variable with the largest proportion of missing values is *Gini* (83.4 %). While the mechanism leading to missingness is not clear, it has been assumed that these data are missing at random, implying that the value of the variable that is missing is not related to the reason behind its absence (Carpenter and Kenward, 2012).

A multilevel multiple imputation (MI) strategy has been implemented to impute missing values. 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 rules (Rubin, 2004). 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. Multilevel MI takes into account the multilevel structure of 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 missing completely at random and missing at random data 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 and Huber Jr, 2011). However, it might be argued that the missing rate of the variable *Gini* is very high. Therefore, models excluding the variable *Gini* have also been fitted. The significance of the association between the other covariates and the outcome was not affected by the imputation of values of *Gini* (results in Appendix B).

The first step of MI is to specify the imputation model, which should include variables that are predictive of the variables with missing values. *GDPpc* has been included in the imputation model since it is predictive of many of the variables with incomplete information; for example, the economic performance of a country is correlated with the educational level (Knack and Keefer, 1997) and with the level of urbanization (Hender-

son, 2003). The mean-centred variable for time has also been included in the MI model in order to account for the effects of time on the variables having missing values (Zhang, 2016), since many of them show a clear trend over the 15-year period.

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

$$m_{ij} = \beta_0 + \beta_1 \log(GDP_{pc_{ij}}) + \beta_2 t_{ij} + u_{0j} + \epsilon_{ij}, \quad (1)$$

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 j_{tb} country, and $\epsilon_{ij} \sim N(0, \sigma_\epsilon^2)$ is the time-varying error term.

The imputation model was estimated using Markov chain Monte Carlo (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 the variable 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 to check the convergence of the parameters of the imputation models. Packages `pan` (Schafer and Graham, 2002) and `mi` `tm1` (Grund et al., 2016) of software R (R Core Team, 2013) were used to run these analyses.

4.2. Fixed effect model for mortality rates

The Hausman test suggested that fixed effect models are preferred to random effect models, since 76 of the 100 imputed datasets have a p -value lower than 0.05. The model of interest is a fixed effects model for the mortality outcome. Denote by NMR_{ij} the outcome variable measured in the i_{tb} ($i = 1, \dots, 4$) survey of the j_{tb} ($j = 1, \dots, 80$) country, and the equation for the fixed effect model is:

$$\begin{aligned} \log(NMR_{ij}) = & \beta_1 \log(GDP_{pc_{ij}}) + \beta_2 Gini_{ij} + \beta_3 Education_{ij} \\ & + \beta_4 Health.expenditure_{ij} + \beta_5 Rural_{ij} + \beta_6 Year_2006_i \\ & + \beta_7 Year_2011_i + \beta_8 Year_2016_i + \gamma_j + \epsilon_{ij}, \end{aligned} \quad (2)$$

where γ_j is the unobserved time-invariant country effect, and $\epsilon_{ij} \sim N(0, \sigma_\epsilon^2)$ is the error term. The inclusion of time dummies allows controlling for time fixed effects, since variation in the outcome is expected to arise from overall time trends, as discussed earlier.

Before the analysis, all the continuous covariates were mean centred. The R package `p1m` (Croissant and Millo, 2008) was used to run these analyses. The same model was fitted to predict $\log(PNMR_{ij})$.

5. RESULTS

The two-level imputation model of Equation 1 was applied to impute the missing values of the covariates *GDPpc*, *Gini*, *Education*, *Health expenditure*, and *Rural*. The potential scale reduction factor associated with the parameters of this model suggests that convergence has been reached. The parameter with the highest potential scale reduction factor is the intercept variance for *Education*, with a value of 1.021. This value is below the typical threshold of 1.050, indicating that convergence has been achieved. After inspection of the correlation matrix, all the covariates were included in the model, since no issues of multicollinearity arose (the strongest correlation was between $\log(GDPpc)$ and *Education*, with a correlation coefficient ranging from 0.48 to 0.59 in the imputed datasets).

Table 3 shows the results of Models 1 and 2, with $\log(NMR)$ and $\log(PNMR)$ as the outcomes, respectively. Among the determinants of interest, $\log(GDPpc)$ has a strongly significant negative association with both outcomes. This result is consistent with a large body of literature on the association between poverty and early-age mortality at the country level (Wagstaff, 2002; United Nations Fund for Population *et al.*, 1999; Neal, 2009). Poorer countries, 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 having a direct impact on children's health (Scott and Duncan, 2000; Nandy *et al.*, 2005).

The association between poverty and neonatal mortality is generally found to be stronger than with post-neonatal mortality. However, this result is not consistent with part of the existing literature, which has found income to have a stronger association with post-neonatal mortality than with neonatal mortality in cross-sectional studies in low- and middle-income countries (Lawn *et al.*, 2005; Neal, 2009; Neal and Falkingham, 2014). It is reasonable to think that the effects of poverty need a time span longer than four weeks after birth to be totally expressed, especially if adopting Mosley and Chen (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, poverty 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, therefore affecting neonatal mortality.

Gini was not significantly associated with the mortality outcomes. A potential pathway through which economic inequality affects infant health outcomes involves widespread adverse housing and sanitation conditions, inadequate investment in public goods, and social and geographical segregation leading to more difficult access to the

TABLE 3
Fixed effect country-level regressions of the log neonatal and post-neonatal mortality rates; Models 1 and 2.

Variable	Model 1: Outcome $\log(NMR)$		Model 2: Outcome $\log(PNMR)$	
	Coefficient	<i>P</i> -value	Coefficient	<i>P</i> -value
$\log(GDPpc)$	-0.132	< 0.01	-0.203	< 0.01
Gini	0.002	0.14	0.003	0.15
Education	-0.002	< 0.01	-0.002	< 0.01
Health expenditure	-0.005	0.42	-0.009	0.42
Rural	-0.002	0.61	0.000	0.98
Year 2005	-0.067	0.01	-0.150	< 0.01
Year 2010	-0.141	< 0.01	-0.308	< 0.01
Year 2015	-0.226	< 0.01	-0.461	< 0.01

health system. However, these pathways have been found not to be significant in determining early-age mortality after taking into consideration other socioeconomic determinants. This result is consistent with Szwarcwald *et al.* (2002) at the micro level, while Mayer and Sarin (2005) found an association between income inequality and early-age mortality at the macro level. However, certain issues might affect analyses of the association between mortality and income inequality at the macro level. Gravelle (1998) stated that the relationship between health and income is curvilinear, meaning that the same amount of money is associated with a higher increase in health among poorer groups than among richer groups. Therefore, a decrease in income inequality deriving from any money transfer from the richest to the poorest necessarily leads to an artefactual correlation between income inequality and health outcomes. It is also worth noting that this analysis considers a sample of low- and middle-income countries, many of which are still in a condition of widespread poverty. It could be reasonable to think that in this context the absolute level of deprivation is the primary socioeconomic determinant of early-age mortality, being more important than the distribution of income within countries. Wilkinson and Pickett (2006) hypothesised that economic inequality might affect health outcomes only in contexts where basic needs are met, which would not be the case in the set of low- and middle-income countries examined in this analysis.

Moreover, the interaction term between $\log(GDPpc)$ and *Gini* has been included in Models 1 and 2, in order to test whether the negative effect of poverty is stronger in countries with greater income inequality. The interaction effect is not significant (*p*-value = 0.93 for neonatal mortality and 0.74 for post-neonatal mortality, results not shown): there is no evidence that the same level of deprivation can have a different impact on neonatal and post-neonatal mortality in a country where economic distribution is more unequal. Among the other variables, *Education* was strongly significant for both outcomes, while *Health expenditure* and *Rural* were not significant predictors of early-age mortality. The adjusted R^2 calculated for each of the imputed datasets ranged from 0.63 to 0.68 for Model 1, and from 0.69 to 0.72 for Model 2. Appendix B presents the

results for Models 1 and 2, excluding the variable *Gini*. These results show that the association between the rest of the covariates and the mortality outcomes is not affected by the imputation of values of *Gini*, which has a very high proportion of missing values.

5.1. Models including measures of non-monetary deprivation

Alternative models including three non-monetary measures of deprivation instead of $\log(\text{GDPpc})$ have been 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 is not too large (the largest correlation coefficient is that between *Electricity* and *Water*, which ranges from 0.64 to 0.66 in the imputed datasets), and no issues of multicollinearity arise. Results are shown in Table 4.

Among the three determinants of risk, access to clean water was the only significant predictor of both mortality outcomes: inadequate water sources are a major cause of water-borne diseases such as those causing diarrhoea (Fewtrell *et al.*, 2005). This determinant had a stronger association with neonatal mortality than with post-neonatal mortality. These results could seem counter-intuitive, since the estimated proportion of neonatal mortality caused by diarrhoea 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 Tomaskovic, 2006). We can however mention the impact of unimproved water supply and sanitation on maternal health during pregnancy, which can affect neonatal mortality (Khan *et al.*, 2011; Manassaram *et al.*, 2005). Comparing the magnitude of the coefficients of *Water* across the two models, this determinant have a stronger association with neonatal mortality than with post-neonatal mortality (the standardized coefficients are $\beta_{\text{Water,NMR}}^* = -0.49$ vs $\beta_{\text{Water,PNMR}}^* = -0.36$).

Access to improved sanitation was not correlated with post-neonatal mortality, while it had a weak association with neonatal mortality (p -value = 0.07), which can be explained by the same factors related to water-borne diseases mentioned earlier in relation to access to clean water (Fewtrell *et al.*, 2005). Access to electricity was not a significant predictor of early-age mortality: while this variable has been linked to the use of solid fuels for cooking and heating, impacting indoor air pollution (Bruce *et al.*, 2000), other dimensions of deprivation are more strongly associated with early-age mortality.

Differently from Model 1, *Gini* has a borderline effect (p -value = 0.08) in the model for $\log(\text{NMR})$, while it was not associated with post-neonatal mortality. None of the other covariates were significantly associated with the mortality outcomes. As with the previous models, this set of covariates explains more the variability of the post-neonatal mortality outcome than of the neonatal mortality outcome (the adjusted R^2 calculated on each of the imputed datasets ranged from 0.64 to 0.69 in Model 3, and from 0.69 to 0.73 in Model 4).

TABLE 4
Fixed effect country-level regressions of the log neonatal and post-neonatal mortality rates; Models 3 and 4.

Variable	Model 3: Outcome log(<i>NMR</i>)		Model 4: Outcome log(<i>PNMR</i>)	
	Coefficient	<i>P</i> -value	Coefficient	<i>P</i> -value
Electricity	0.002	0.45	0.001	0.80
Water	-0.010	< 0.01	-0.014	0.01
Sanitation	-0.009	0.07	-0.012	0.13
Gini	-0.005	0.08	-0.006	0.15
Education	0.000	0.77	0.000	0.77
Health expenditure	-0.010	0.17	-0.016	0.21
Rural	0.008	0.13	0.014	0.12
Year 2005	-0.044	0.09	-0.116	0.01
Year 2010	-0.092	0.04	-0.238	< 0.01
Year 2015	-0.153	0.02	-0.354	< 0.01

6. CONCLUSION

While determinants of infant and child mortality have received broad attention in the literature, socioeconomic factors impacting neonatal mortality have only recently interested demographers and health researchers. A decrease in under-five mortality observed globally has not been followed by an equal drop in neonatal deaths (Pathirana *et al.*, 2016). By making use of World Bank data from different surveys of 79 low- and middle-income countries, this study has assessed whether poverty and economic inequality have different patterns of association with deaths occurring in and after the first month of life, while controlling for potential confounders. Poverty and access to clean water were found to be significant predictors of neonatal and post-neonatal mortality. Four pathways through which poverty can affect early-age mortality have been identified: reduced access to health care (Lawn *et al.*, 2005), environmental aspects (Jain, 1985; Rutstein, 2000), nutritional deprivation both in mothers and children (United Nations Fund for Population *et al.*, 1999), and maternal education (Neal, 2009). Access to clean water was associated with water-borne diseases, such as those leading to diarrhoea. Both poverty and access to clean water here were found to have a stronger association with neonatal than with post-neonatal mortality. Economic inequality does not seem to be a predictor of early-age mortality. It should be taken into account that the sample analysed in this study contains many countries in which the threshold of absolute deprivation has not been overcome. In such contexts absolute deprivation, rather than its distribution, has been found to have a major effect on health outcomes (Wilkinson, 1994; Marmot, 2005). The pragmatic consequences of poverty and deprivation are therefore of primary importance for early-age mortality.

Two main limitations affect this study. First, several uncaptured factors – among others, measures of political context, social norms and cultural beliefs – could be the reason for the unexplained heterogeneity in NMRs and PNMRs. For instance, the percentage

of GDP aimed at health expenditures could not be informative about the effectiveness of health services and policies, as well as about their coverage across the population. Second, some variables, like the Gini coefficient, had a high proportion of missing data, as explained in Section 4.1.

By identifying the macro-level socioeconomic factors associated with early-age mortality, this study has implications for health and social policies that aim to reduce early-age mortality. Policies oriented towards the reduction of poverty and the extension of the clean water supply can have a positive effect on post-neonatal mortality, while maternal education is the only other significant determinant of early-age mortality. These findings can partly explain the relative stagnation in NMRs observed over the last decades, in comparison to infant and child mortality. Further research might involve the study of causal paths leading from deprivation to early-age health outcomes. It might also be of interest to study the association between deprivation and other early-age health outcomes beyond mortality, like birth weight or infant morbidity.

APPENDIX

A. LIST OF THE SELECTED COUNTRIES

The selected countries (79 in total) are ³:

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 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, Zimbabwe.

³ The observations referring to Somalia have been excluded, since this is the only country having no data for GDP per capita, which needs to be complete since it is a variable used as a predictor in the imputation model.

B. MODELS FOR $\log(NMR)$ AND $\log(PNMR)$ EXCLUDING GINI

TABLE 5
Fixed effect country-level regressions of the log neonatal and post-neonatal mortality rates; Models 1 and 2, Gini not included.

Variable	Model 1 :Outcome $\log(NMR)$		Model 2: Outcome $\log(PNMR)$	
	Coefficient	P-value	Coefficient	P-value
$\log(GDP\ pc)$	-0.128	< 0.01	-0.196	< 0.01
Education	-0.001	< 0.01	-0.002	0.03
Health expenditure	-0.007	0.27	-0.012	0.29
Rural	0.001	0.65	0.005	0.29
Year 2005	-0.065	< 0.01	-0.147	< 0.01
Year 2010	-0.137	< 0.01	-0.303	< 0.01
Year 2015	-0.219	< 0.01	-0.450	< 0.01

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SUMMARY

While socioeconomic determinants of infant mortality have received substantial attention in the literature, determinants of neonatal and post-neonatal mortality have rarely been analysed and compared. By making use of World Bank data, this country-level study aims to highlight different patterns of association of poverty and income inequality with mortality occurring in the neonatal and post-neonatal periods, controlling for other socioeconomic variables. Poverty is found to be the major determinant of both mortality outcomes, while economic inequality is not a predictor of early-age mortality. This is perhaps because this analysis considers only countries where many households may lack resources for an adequate living standard; in such a context, the absolute level of poverty, rather than its distribution, has an effect on infant health. Moreover, a non-monetary manifestation of poverty, namely access to clean water, is a predictor of both mortality outcomes, probably due to its association with water-borne diseases. By identifying the socioeconomic factors associated with early-age mortality, this study has implications for social policies designed to tackle neonatal and post-neonatal mortality and can partly explain the stagnation in neonatal mortality rates observed over the last decades.

Keywords: Neonatal mortality; Post-neonatal mortality; Poverty; Inequality.