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Under-five Mortality in Developing Countries: Will the Millennium Development Goal Be Achieved?

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Abstract

High levels of child mortality in the developing countries led the United Nations to include a significant reduction of under-five mortality rates among the eight Millennium Development Goals (MDGs) to be reached before 2015. In particular, the target of MDG 4 is to reduce the under-five mortality rates in every developing country by two thirds with respect to the levels reached in 1990. This article contributes to the debate on whether the target of MDG 4 will be reached by 2015; it also offers policy recommendations. We observe 110 countries defined by United Nations as "less" or "least" developed. The time-series-macro data used in the study come mainly from the United Nations "MDGInfo" database. Additional data come from WHO, UNICEF, UNDP and World Bank databases. The availability of a large amount of comparable data at the national level makes the quantitative cross-country approach particularly suitable for describing and comparing the intensity and main features of child mortality in different regions and countries. In our article, we: 1) provide an overview of the general context of developing countries; 2) analyze (using principal component analysis and cluster analysis) aspects of child mortality to highlight its different patterns and group together the considered countries in homogeneous clusters; 3) apply and update a methodology used by international agencies to monitor the outcomes obtained by each country in the reduction of child mortality and to estimate the chance each country has to reach MDG 4 (taking into account the trends shown since 1990); and 4) utilize linear regression models to identify the main social and economic determinants of the gaps that exist for each country in 2010 between the observed under-five mortality rates levels and those required to achieve the target. Our study shows that in 50 of 110 countries, mostly in sub-Saharan Africa, the average annual rate of reduction in under-five mortality rates observed so far will not be sufficient to meet MDG 4.

Keywords

Under-five mortality, Millennium Development Goal, developing countries, comparative analysis, cluster analysis

Introduction

Child mortality is one of the most sensitive and commonly used indicators of the health, socio-demographic and economic development of populations. The different regions of the world are characterized by profound heterogeneities in child-mortality levels, patterns and dynamics. The level of child mortality in developing countries has been described by the United Nations in terms of a "human disaster" (United Nation Millennium Project 2005b).

In September 2000, during the "United Nations Millennium Summit", in the hope of improving the quality of life in developing countries, the international community adopted the "Millennium Declaration". Eight Millennium Development Goals (hereafter referred to as MDGs) were identified as strategic aims to be reached by 2015, and a system of indicators was set up, which allows poor countries and donor communities to monitor the distance covered toward achieving each goal. The persistence of high levels of child mortality in the developing countries led the United Nations to include a significant reduction of these levels in the eight MDGs. Specifically, MDG 4 aims to reduce under-five mortality rates (hereafter referred to as U5MRs) in every developing country by two thirds the levels reached in 1990.

The availability of a large amount of comparable data at the national level makes the quantitative cross-country approach particularly suitable to describe and compare the intensity and main features of child mortality in different regions and countries (Houweling et al. 2005). Moreover, the availability of time series for many indicators allows for the evaluation of each country or region's possibilities of reaching MDG 4. According to recent data, it seems evident that, as a consequence of the differences existing in the respective initial contexts and of the kind of efforts made and their effectiveness, not all the countries involved in reaching the goal will succeed in doing so. In fact, although several countries are on track to achieve MDG 4, many others are falling a long way short. Thus, a "big push" is needed (Agénor et al. 2006).

On the basis of these considerations, and at only a short time distance from the 2015 deadline, this article contributes to the international debate on under-five child mortality and MDG 4 and advances knowledge useful to develop relevant policies to reach MDG 4. The article describes the situation of a large number of developing countries and attempts to identify the main causes of the different possibilities they have of reaching MDG 4. In what follows, we recall the recent relevant literature and provide an overview of the general context of developing countries. After describing data and methods used, some aspects of child mortality are analyzed to highlight its different patterns, as well as to classify the observed countries in homogeneous groups. Subsequently, taking into account the trends shown since 1990, we estimate the chance each country has to reach MDG 4. Finally, we try to identify the main social and economic determinants of the gaps that exist for each country in 2010 between the observed U5MR levels and those required to achieve the target. The last section, based on obtained results, contains some suggestion for political actions in the fight against child mortality.

Theoretical background

Child mortality is "one of the cornerstones" of demographic dynamics (Masuy-Stroobant and Gourbin 1995). It has been used for the description of demographic transitions in populations of more developed countries (hereafter referred to as MDCs). Subsequently, elaborate models and methods were applied to the analysis of developing countries, which exhibited (or still exhibit) levels and patterns of infant and child mortality "typical for Europe in the past" (Tymicki 2009: 560).

The association between deprivation and low survival levels was already documented in the first half of the nineteenth century, and support of the strong inverse relationship between socio-economic development and mortality has been found repeatedly since the Second World War (Masuy-Stroobant 2001). Research on the reduction of infant and child mortality in Europe has identified a broad series of determinants that can explain the present situation in developing countries.

Some scholars, in particular Bougeois-Pichat (1951) and Lalou (1997), divided the causes of death during the first months and years of life between endogenous and exogenous factors. The first category refers to causes associated with biological and genetic factors that influence survival chances immediately after birth, such as fetal malformation, low birth weight or birth trauma, high susceptibility to infections and abnormalities of body functions, among others. The second category includes the causes associated with the postnatal environment, depending on the pathological health and socio-economic conditions in which the child lives, such as poor hygienic and/or sanitary conditions, malnutrition, epidemics and infections, among others. However, a rigid distinction between endogenous and exogenous causes is difficult because many endogenous factors are strongly influenced by environmental factors. Moreover, it has been demonstrated that high fertility patterns typical of the past had effects on infant and child survival, mainly through shortened birth intervals, parity and family size, among others (Ewbank and Preston 1990).

The most frequently referenced approach in subsequent analyses dealing with infant or child mortality determinants is that proposed by Mosley and Chen (1984), which includes both biological (proximate) and socio-economic variables and assumes that the latter determinants work through a common set of the former. The authors grouped the biological/proximate determinants into five categories (Mosley and Chen 1984: 32)

1. *maternal factors*: age, parity, birth interval;
2. *environmental contamination*: air, food/water/fingers, skin/soil/inanimate objects, insect vectors;
3. *nutrient deficiency*: calories, proteins, micronutrients;
4. *injury*: accidental, intentional;
5. *personal illness control*: personal preventive measures, medical treatments.

The socio-economic determinants were grouped into three broad categories (Mosley and Chen 1984: 34)

1. *individual-level variables*: productivity (skills, measured by mother's educational level, health, represented by childcare skills/preferences and mother's time for prenatal visits), traditions/norms/attitudes (power relationships within the household, value of children, beliefs about disease causation, food preferences);
2. *household-level variables*: income/wealth effects (food availability, quality of water supply, clothing/bedding, housing conditions, fuel and energy availability, transportation, hygienic, preventive and sickness care, and access to information);
3. *community-level variables*: ecological setting (climate, temperature, altitude, season, rainfall), political economy (organization of production, physical infrastructure, political institutions), health system (institutionalized actions mandated by law to affect the health of the population at large, cost subsidies, public information/education/motivation programs, the role of technology).

The key advantage of the Mosely and Chen (1984) model lies in its organization of seemingly disparate measures into a coherent framework in which they are linked to one another and to child survival.

Five macro-social change theories, that have attempted to explain the variation of infant (and child) mortality across the developing countries, are also relevant to our study (Frey and Field 2000)

1. *modernization theory*: industrialization and economic development promote specific forms of human well-being (e.g. education, housing, nutrition, health care, sanitation, public services) that reduce childhood mortality (Rostow 1960; So 1990);
2. *dependency/world-systems theory*: in a capitalist world system, characterized by a dependency of peripheric countries from core countries, the economic surplus of the dependent countries is taken from core countries instead to be invested in economic growth and public programs designed to increase human well-being, including mortality in the first years of life (Chase-Dunn 1989; Chase-Dunn and Grimes 1995; Shannon 1996);
3. *economic disarticulation theory*: disconnections and inequalities of various sectors of the national economic system, due to over-reliance on external markets and foreign capital, lead to a reduction in public funds that are channeled to health and human welfare (Amin 1974; Stokes and Anderson 1990);
4. *developmental state theory*: activist governments can engage in redistributive efforts that reduce mortality in the first years of life, such as increasing the population's well-being and providing educational, health and other social services (Evans 1995; Skocpol 1985);
5. *gender stratification theory*: in societies characterized by social, economic and educational disparities between males and females, improvement in the societal status of women decreases infant and child mortality. Increased female education is identified as one of the most important ways of reducing infant and child mortality (Boehmer and Williamson 1996; Shen and Williamson 1997; Ward 1984).

In particular, John C. Caldwell (1989, 1993) elaborated three main hypotheses on the mechanisms through which maternal education exerts its effects on the health of children. First, mothers become less "fatalistic" about illness and adopt many of the alternatives in child care and therapeutics. Moreover, an educated mother is more likely to be listened to by doctors and nurses. Second, the education of women greatly changes the traditional balance of familial relationships with profound effects on childcare.

Data and methods

To reach our purposes, we take into consideration 111 countries, all with a population of at least 1 million in 2010 and defined, according to the United Nations classification, as "less" or "least" developed countries (hereafter referred to as LDCs; for an overview of the considered countries see figure 1)[1].

The time-series macro-data used come mainly from the "MDGInfo" database (United Nations 2012), which provides about 70 indicators referring to all the regions and countries of the world. Moreover, additional data come from the "Statistical Information System" (World Health Organization 2013),

[1] According to the United Nation definition, "less developed countries" comprise all countries of Africa, Asia (excluding Japan), Latin America and the Caribbean (excluding Haiti) plus Melanesia, Micronesia and Polynesia; "least developed countries" comprise 33 countries in Africa, 9 in Asia, 5 in Oceania plus Haiti; "more developed countries" comprise Europe, Northern America, Australia/New Zealand and Japan.

from the "Child Info System" (UNICEF 2012), from the statistics of the "Human Development Report" (UNDP 2013), and from the "World Development Indicators" (World Bank 2013).

U5MR, the indicator chosen to determine the target of MDG 4 and, therefore, our basic reference to measure child mortality, is considered an excellent measure of child health and survival since at present deaths among children under the age of 5 account for about 4/5 of global mortality among children under the age of 18 (United Nations 2013).

With regard to the techniques of analysis employed, after a description of the general context based on U5MR levels and on their variations from 1990 to 2010, principal component analysis (hereafter referred to as PCA) and cluster analysis methods are applied to group together the considered countries.

The PCA estimates new synthetic variables (principal components) obtained by the linear combination of the original ones; they represent the widest possible portion of the total variability. This facilitates the exploration of the associations between variables and also the collocation of the observed countries in relation to those variables on the factor plane. The variables included in the PCA are: the under-five mortality rank, the percentage of variation of the rates from 1990 to 2010, the difference between male and female U5MRs, the ratio between deaths in the first year of life and deaths in the first five years (hereafter referred to as $D_{0\text{-}1}/D_{0\text{-}5}$), and the percentage of deaths by eleven main causes (HIV/AIDS, diarrhoea, measles, malaria, pneumonia, prematurity, birth asphyxia, neonatal sepsis, congenital anomalies, injuries, among others).

The cluster analysis was performed using "Ward's method," which creates partitions that ensure the minimum intra-class and maximum inter-class variability.

In the PCA and in the cluster analysis we transformed the U5MR into a relative unit free index (called under-five mortality rank) that varies between 0 and 1, using the formula:

$$x\text{-}index = [x\text{-}min(x)]/[(max(x)\text{-}min(x)],$$

where $min(x)$ and $max(x)$ are the lowest and highest values the variable x attains, respectively 5.9‰ (Cuba) and 188.8‰ (Sierra Leone). Generally speaking, such an indicator does not change the overall picture of U5MR among countries although its values are weighted according to the worldwide range variation.

In the subsequent section of the article we update a methodology that has been used by UNICEF, WHO, World Bank and the United Nations Population Division (see UNICEF, WHO, World Bank and United Nations Population Division 2007) to monitor the outcomes obtained by each country in the reduction of child mortality during the observed twenty years[2].

[2] A new Bayesian B-spline bias-reduction model (Alkema, New 2013) was estimated on September 2013 and it was applied in a very recent analysis by UN IGME (2013). The elaboration included in this paper were completed roughly in the same period, but it has been impossible to update them according to the new estimation approach because of the lack of some necessary data for cluster and regression analysis we show in the next sessions. However, the new approach and estimates do not contradict, generally speaking, the results and trends that outcome from this paper.

The average annual rate of reduction in under-five mortality (hereafter referred to as AARR) for each considered country is calculated as follows:

$$AARR(t_1,t_2) = 1/(t_2-t_1) \times \ln [{}_5q_0(t_2)/{}_5q_0(t_1)],$$

where t_1 and t_2 are the starting year and the final year of the observed period (respectively 1990 and 2010) and ${}_5q_0$ is the U5MR. In addition, according to the trend observed so far, both the possibility each country has of reaching the target (or to be "on track"), and the number of countries which should reach it for each cluster are estimated. In particular, following the above mentioned methodology, each country is defined as "on track" if it has an U5MR lower than 40‰, or has an U5MR higher than 40‰ and an AARR higher than 4.4%. In fact, according to the quoted estimates, in order to achieve the goal, the U5MRs would have to decrease globally by 4.4% every year in the 1990-2015 period.

Last, linear regression models are applied to identify the determinants of the "performance" attained by each of the considered countries on the way towards MDG 4.

The dependent variable is for each country the difference between the U5MR level required in 2010 to achieve the target and that observed in the same year.

With regard to independent variables, characteristics both directly and indirectly related to childhood mortality were considered according to the literature and to the availability of data.

The first group of variables comprises: adolescent fertility rate, antenatal care coverage, births attended by skilled health personnel, low birth weight newborns, immunization coverage in the first year of life (distinctly for measles, diphtheria, pertussis, tetanus and hepatitis B), and quota of children stunted and underweight for their age.

The second group of variables comprises: access to improved drinking-water source; access to improved sanitation; density of physicians; government expenditure on health per capita, gross national income per capita; quota of population living below US$1.25 a day; net school enrolment ratio (distinctly for primary, secondary and tertiary schools); net school enrollment ratio of females; gender parity index in school enrolment (distinctly for primary, secondary and tertiary schools); adult literacy rate; female literacy rate; gender inequality index; percentage of women employed in the non-agricultural sector; carbon dioxide emission per capita; official development assistance per capita; direct foreign investment; turnover ratio of stocks traded; external debt stocks and net flows; energy use; tax revenue; labour force employed in the industrial sector.

Standardized predictors were introduced sequentially in a stepwise procedure; only statistically significant and uncorrelated ones were included in the final models.

Under five mortality in the world: a synthetic picture of recent dynamics and characteristics

In 1990, which is the baseline for defining MDG 4, 12.4 million children under five died worldwide. That count reached 7.6 million in 2010, a drop of around 35% in 20 years (United Nations 2013). The progress in child survival in the world as a whole is remarkable, even though many regional disparities persist (table 1).

The region with the highest level of U5MR remains sub-Saharan Africa, which had, as a whole, a rate of 121‰ in 2010 and was characterized by the lowest registered improvement (U5MR variation between 1990 and 2010 was -30.5%). Southern Asia was the region with the second highest U5MR in 2010 (66‰), with a variation of -43.6% during the observed period. Collectively, these two geographical areas account for 82% of all child deaths on a global scale (United Nations 2013).

Central Asia and the Caucasus, as well as Oceania, are characterized by rates respectively of 52‰ and 45‰, while the other regions of the world do not exceed 32‰. In particular, the U5MR is about 7‰ in MDCs. In the last twenty years, the best performances in the fight against child mortality have been observed in Northern Africa (-67.1%) and in Eastern Asia (-62.5%).

The countries with the highest U5MRs (35 over 40) are located mainly in sub-Saharan Africa. Among

Table 1. Under-five mortality rates (U5MRs) in 2010 (‰) and variations in the period 1990-2010 (%) by world regions and worst and best six countries

World regions	UFMRs 2010 (‰)	U5MRs variations 1990-2010 (%)	Worst and best six countries	U5MRs 2010 (‰)	Worst and best six countries	U5MRs variations 1990-2010 (%)
World	57	-35.2	Sierra Leone	188.8	Congo	63.4
Developed Countries	7	-53.3	Somalia	180.0	Swaziland	13.8
Developing Countries	63	-35.1	Mali	178.9	Haiti	5.7
Least Developed Countries	110	-35.3	Congo	169.9	Central Afr. Rep.	-3.7
North Africa	27	-67.1	Chad	171.3	Cameroon	-7.3
Sub-Saharan Africa	121	-30.5	Central Afr. Rep.	164.6	Lesotho	-8.8
Caucasus & Central Asia	45	-41.6	…		…	
Eastern Asia	18	-62.5	Oman	9.4	Lao PDR	-73.1
Southern Asia	66	-43.6	Chile	8.8	Lebanon	-73.2
South Eastern Asia	32	-54.9	Qatar	8.1	Peru	-75.1
Western Asia	32	-52.2	Malaysia	6.8	Egypt	-75.8
Latin America & Caribbean	23	-57.4	Belarus	6.1	Saudi Arabia	-77.5
Oceania	52	-30.7	Cuba	5.9	Turkey	-80.1

Source: our elaborations on United Nations (2013a) data

these, the worst are Sierra Leone (188.8‰) Somalia (180.0‰) and Mali (178.9‰). On the other hand, the lowest levels among developing countries are found in Cuba, Malaysia and Belarus (respectively 5.9‰, 6.1‰ and 6.8‰). Child mortality has declined all over the world since 1990 with only three exceptions: Congo (63.4%); Swaziland (13.8%) and Haiti (5.7%). The best improvements are in Turkey (-80.1%), Saudi Arabia (-77.5%) and Egypt (-75.8%).

The heterogeneity observed of U5MRs and their variation among regions and countries is significantly amplified if we examine other equally important aspects of the phenomenon, such as gender differences, the incidence of mortality according to different ages, and the frequency of the different causes of death. As explained in the “Data and methods” section, we used the PCA, in order to investigate how the different characteristics of child mortality combine with the general levels and dynamics of the phenomenon observed so far. In other words, the PCA aim is to summarize the previously quoted “proximate” 15variables – not independent of each other – for the 111 statistical units corresponding to the considered countries.

The four principal components with an auto-value greater than one were considered; they explain 69.7% of the total variability (table 2). The first component absorbs the larger part of the variance in the Rotation Sums of Squared Loadings (26.8%). It summarizes first of all the intensity and the trend

of under-five mortality, set together with the gender distribution and against the proportion of infant mortality on child mortality. The obvious former outcome highlights how the countries that reached the lowest levels of under-five mortality in 2010 are those that observed the greatest improvements in the previous twenty-year period. Moreover, males have higher child mortality rates than females at early ages, and an inverse relation links under-five mortality rates with infant mortality levels. In addition, inverse relations emerge between the intensity/trend of under-five mortality and the mortality due to prematurity. Finally, a positive relation appears with malaria and measles, which are among the most important causes of children's deaths in the developing countries. The second component explains 20.5% of the variance and highlights diarrhoea and pneumonia as causes of death. This component also shows an inverse relation between the latter causes of death and those due to congenital anomalies and injuries. The third component captures 12.2% of variability, and is directly linked to two specific neonatal causes of death particularly widespread in developing

Table 2. Component Matrix[(a)]

Variables	Component 1	Component 2	Component 3	Component 4
Under-five mortality rank. 2010	0.782	0.507	-0.055	0.149
Under-five mortality rates variation (%). 1990-2010	0.639	0.056	-0.140	0.358
Male/female deaths ratio. 2010	0.584	0.153	0.076	0.133
D_{0-1}/D_{0-5}. 2010	-0.771	-0.426	0.063	-0.214
Deaths due to HIV/AIDS (%). 2008	0.321	-0.165	0.027	0.686
Deaths due to diarrhoea (%). 2008	0.399	0.797	0.123	0.065
Deaths due to measles (%). 2008	0.431	-0.069	0.410	0.078
Deaths due to malaria (%).2008	0.705	0.281	-0.113	0.211
Deaths due to pneumonia. (%). 2008	0.037	0.904	0.002	-0.099
Deaths due to prematurity (%). 2008	-0.822	-0.243	-0.251	0.214
Deaths due to birth asphyxia (%). 2008	-0.318	0.079	0.837	0.069
Deaths due to neonatal sepsis (%). 2008	0.180	0.188	0.860	0.021
Deaths due to congenital anomalies (%). 2008	-0.487	-0.721	-0.260	-0.115
Deaths due to other causes (%). 2008	-0.024	-0.373	-0.133	-0.801
Deaths due to injuries (%). 2008	-0.267	-0.538	-0.100	-0.264
% of explained variance	*26.8*	*20.5*	*12.2*	*10.2*

(a) Rotation Method: Varimax with Kaiser Normalization.
Source: our elaborations on United Nations (2013a) and World Health Organization (2013) data

countries: birth asphyxia and neonatal sepsis. The last component, which absorbs 10.2% of the total variance, is strongly linked to HIV/AIDS. It underlines the poor distribution of immunization instruments and treatments (e.g. vaccinations and adequate therapy) in countries that need them most.

In synthesis, the PCA results show four main factors (or patterns) of mortality according to their causes: the "infective" causes of death, the "environmental and viral" causes related to the socio-sanitary and health conditions, the "endogenous" causes related to the first periods of life and, finally, a specific "epidemic" cause of death (e.g. HIV/AIDS).

As specified in the "data and methods" section, we applied the hierarchical classification analysis (cluster analysis) to classify the single observed countries inside groups as homogeneous as possible, defined by the factorial scores of PCA attributed to each country. The best classification obtained is the one formed in seven clusters, ordered according first to the child mortality intensity, and second to its relative variation (table 3).

Cluster 1: presents the lowest U5MR in 2010 and one of the widest declines in the period 1990- 2010; deaths are concentrated in the first year of life and, among the causes of death, prematurity, congenital anomalies and "other" causes prevail. It includes only three countries of North Africa (Egypt, Libya

and Tunisia) and six of Western Asia (Jordan, Kuwait, Lebanon, Oman, Saudi Arabia and Syria).

Cluster 2: shows the same lowest mortality level of cluster 1 in 2010. However, it shows slower progress than cluster 1 in the considered period (1990-2010). Child mortality occurs mainly during the first year of life and, besides the causes of death listed in the previous cluster and still widely present in this group, birth asphyxia and neonatal sepsis emerge. Injuries emerge as a leading cause of death as well. Twenty-one countries are grouped in this cluster. Eleven of them are in Latin America and the Caribbean (including Argentina, Brazil, Colombia and Venezuela); the others are located mainly in the Caucasus (Belarus, Moldova, Ukraine and the Russian Federation) and in different regions of Asia (such as China, Malaysia and Sri Lanka).

Table 3. Characteristics of the 7 clusters (mean values) and number of included countries

Variables	Clusters						
	1	2	3	4	5	6	7
Under-five mortality rank, 2010	0.06	0.06	0.11	0.21	0.31	0.52	0.64
Under-five mortality rates var. (%), 1990-2010	-54.83	-45.77	-53.00	-55.14	-16.17	-34.87	-23.56
Male/female deaths ratio, 2010	3.33	3.76	4.70	6.67	9.67	11.00	12.59
D_{0-1}/D_{0-5}, 2008	85.93	85.82	85.04	83.22	70.65	68.64	63.17
Deaths due to HIV/AIDS (%), 2008	0.11	0.67	0.85	0.00	26.33	1.62	4.26
Deaths due to diarrhea (%), 2008	3.67	2.57	7.60	15.40	9.17	18.54	15.19
Deaths due to measles (%), 2008	0.00	0.05	0.20	0.80	2.17	1.69	0.93
Deaths due to malaria (%),2008	0.00	0.19	0.00	1.33	1.67	3.15	20.15
Deaths due to pneumonia, (%), 2008	8.89	6.67	17.50	19.33	12.50	20.92	16.74
Deaths due to prematurity (%), 2008	29.67	17.24	20.25	16.73	13.67	9.54	9.52
Deaths due to birth asphyxia (%), 2008	5.44	9.57	8.80	11.73	8.17	9.08	7.33
Deaths due to neonatal sepsis (%), 2008	1.11	4.71	2.80	7.33	4.33	6.08	4.81
Deaths due to congenital anomalies (%), 2008	23.89	21.81	12.35	5.40	5.00	2.62	2.41
Deaths due to other causes (%), 2008	20.22	27.57	25.00	19.00	14.83	23.31	16.52
Deaths due to injuries (%), 2008	6.56	9.00	4.95	2.67	2.50	3.38	2.07
Number of countries	*9*	*21*	*20*	*15*	*6*	*13*	*27*

Source: our elaborations on United Nations (2013a) and World Health Organization (2013) data

Cluster 3: highlights a low mortality in 2010, which has decreased remarkably since 1990, notwithstanding the remaining diffusion of "environmental" death causes (diarrhea and pneumonia). This cluster includes twenty countries in three different regions: ten of Latin America and the Caribbean (such as Bolivia, Ecuador, Paraguay and Peru), three of the Caucasus (Armenia, Georgia and Kazakhstan) and seven located in different regions of Asia (such as the Philippines, Mongolia, Iraq and Turkey).

Overall, the first three clusters differ from the others not only in the low intensity of child mortality and in its significant diminution since 1990, but also in the importance of the different causes of death. Most of the reduction in child mortality in the considered period occurred in older children. Because this was not accompanied by an appreciable reduction of neonatal deaths from causes such as prematurity or congenital anomalies, these began to account for a higher proportion of total under-five mortality, not considering other accidental causes and injuries.

Generally speaking, the remaining four groups of countries are characterized by high mortality in the ages from 1 to 5; the largest part of the child deaths in these groups are caused by exogenous causes (as previously defined) and communicable diseases (including pneumonia, diarrhea, malaria, measles, and HIV/AIDS).

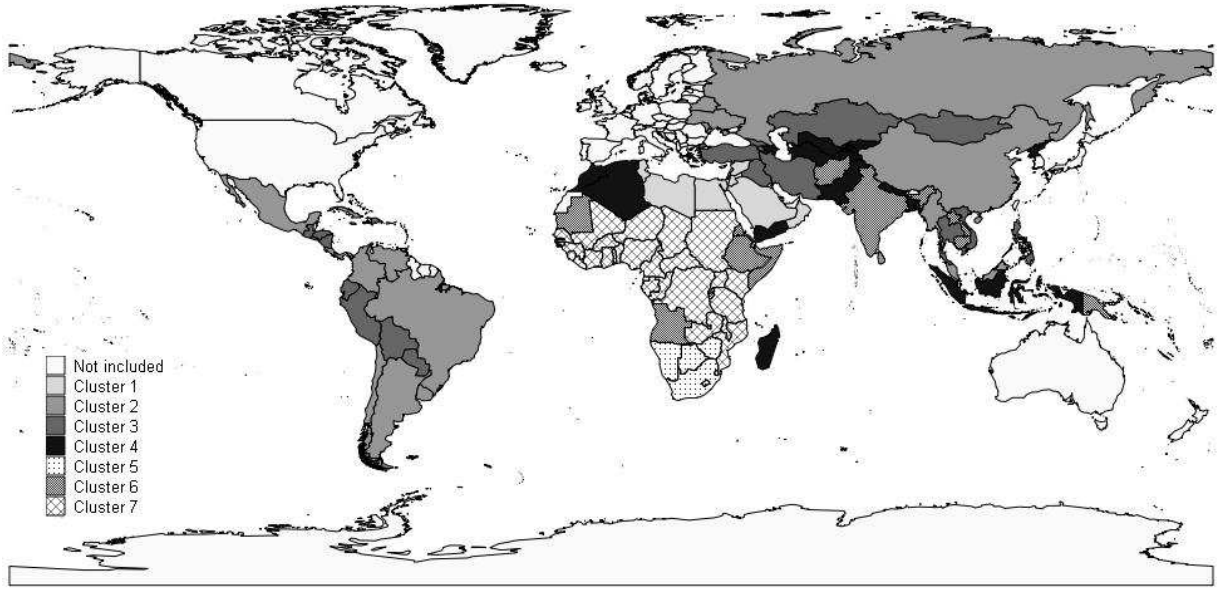
Cluster 4: shows a middle-high mortality in 2010, despite the great reduction which occurred in the previous twenty years; the most prominent causes of death are diarrhea and pneumonia, followed by the neonatal ones (birth asphyxia and neonatal sepsis) that show the highest mean values among the clusters. On the whole, the countries grouped in cluster 4 seem to have followed the same route as those in cluster 3, but making less progress. They consist of five Caucasian countries (including Turkmenistan and Uzbekistan), three African countries (Algeria, Madagascar and Morocco) and seven Asian ones (including Bangladesh, Indonesia, Korea DPR and Pakistan).

Cluster 5: assumes a relatively middle-high mortality in 2010. Nevertheless it also shows the smallest U5MR variation for the observed twenty years, due to the wide diffusion of mortality mainly through HIV/AIDS; also deaths due to measles reduce the role played by the other causes. This group includes only six South-East African countries (Botswana, Lesotho, Namibia, South Africa, Swaziland and Zimbabwe). For such countries, no matter how difficult it may be to implement interventions for the care of pediatric HIV/AIDS, controlling this disease is clearly a priority.

Cluster 6: is characterized by the second highest child mortality level. The relative improvements conducted during last twenty years seem insufficient to achieve significant results in the fight against under-five deaths. All the considered causes of death seem to contribute to this, with "environmental" diseases (diarrhea and pneumonia) emerging as of particular importance, while neonatal death causes are overshadowed. Six South-Eastern African countries (Burundi, Eritrea, Ethiopia, Mauritania, Rwanda and Somalia), four Asian ones (Afghanistan, Cambodia, India, and Laos PDR), Angola, Haiti and Papua New Guinea are included in this group. In total there are thirteen countries in this cluster.

Cluster 7: assumes the highest under-five mortality level and, together with cluster 5, differs from the previous one above all for the slightness of the reductions. More than elsewhere, child mortality in these countries involves older children and males and is characterized by a very high quota of malaria, but other diseases are also widespread. Twenty-seven African countries are grouped in this cluster: twenty West-Central African countries (including Benin, Congo, Mali, Nigeria and Senegal) and seven East-South African ones (including Kenya, Mozambique and Tanzania).

Figure 1. Classification of the observed countries by cluster



Source: our elaborations on United Nations (2013a) and World Health Organization (2013) data

Looking at the worldwide distribution of clusters (figure 1), significant differences exist between the usual geographical aggregation (shown in table 1) and the aggregation that results from the PCA analysis on child mortality.

A dynamic point of view: evolution of child mortality in achieving MDG 4

As previously recalled, the MDG 4 target foresees a two thirds reduction of under-five mortality, to be achieved over a 25 year period (from 1990 to 2015) and is based on global historical trends (as observed over the previous 25 years). Thus, the U5MRs should on average fall from 74.7‰ to 24.9‰ for all the countries included in our analysis. The decrease up to 2010 is of an average of 45.3‰, thus the largest effort remains to be made if the target is to be achieved.

UNICEF, WHO, World Bank and United Nations Population Division (2007) have monitored and published outcomes on reducing U5MRs to date; thy produced estimates from every region and country in the world. We applied the methodology used to arrive at those estimates (as already explained in the "data and methods section") and updating those estimates to 2010.

Our analysis (see table 4) shows that between 1990 and 2010 the AARR is only 3.5% among all the considered countries. In this scenario, only 61 countries are "on track" for MDG 4 in 2010 (almost 55% of the total). To reach the target, the pace of change must accelerate. However, the global numbers mask wide variations between regions and countries. Eastern Asia, Latin America and the Caribbean are considered to be mostly "on track" in achieving MDG 4. At the other extreme, the rate in sub-Saharan Africa has declined by just 1.5%.

Grouping the countries into the seven clusters described above, table 4 shows, for each cluster, the average values of U5MRs in 1990 and 2010, and those required for reaching the target in 2015. Furthermore, it contains the AARRs observed during the 1990-2010 period, those required to meet the target, and the number of countries "on track".

Our elaborations show that there are substantial differences between the first four and the last three clusters. In fact, while in clusters 1, 2, 3 and 4 the total number of countries that presumably will reach the target is 59 out of 65, in clusters 5, 6, and 7 it is only 2 out of 46. Such a huge difference is mainly linked to the low level of success in the fight against mortality before 2010.

Table 4. Under-five mortality rates in 1990 and 2010, and required by MDG in 2015, average annual rate of reduction in under-five mortality (1990-2010) observed and required (means values by clusters) and number of countries "on track" toward the MDG target

Variables	Clusters							Total
	1	2	3	4	5	6	7	
Under-five mortality rate, 1990 (‰)	43.7	33.9	64.3	111.3	83.5	171.7	181.4	74.7
Under-five mortality rate, 2010 (‰)	17.8	18.0	28.5	48.1	68.7	112.4	135.0	45.3
Under-five mortality rate required, 2015 (‰)	14.4	11.8	21.6	37.2	27.3	56.8	61.8	24.9
AARR observed, 1990-2010 (%)	4.5	3.4	4.3	4.3	1.0	2.5	1.6	3.5
AARR required, 1990-2010 (%)	4.5	4.2	4.4	4.4	4.5	4.4	4.3	4.4
N. of countries "on track" toward MDG	*9*	*20*	*18*	*12*	*0*	*2*	*0*	*61*

Source: our elaborations on United Nations (2013a) and World Health Organization (2013) data

Countries in cluster 1 (that are all "on track") started in 1990 at U5MRs around 40‰ on average (that is the UNICEF, WHO, World Bank and United Nations Population Division limit) and in 2010 reached values very close to the MDG 4 target, mainly due to the coincidence of the observed and required AARR. Cluster 2 presents a U5MR lower than 40‰ in 1990 (33.9‰). Thus, even if the AARR is lower on average (only 3.4%) than the required one, all the countries included in this cluster (except Myanmar) should be "on track" to reach the goal in 2015. Countries in cluster 3 had an average U5MR (64.3‰) much higher than the established limit, but the efforts made until now to reduce it will presumably permit them to reach the target within five years (with the exceptions of Guatemala and Iraq). Countries in cluster 4 have not yet recorded a mean value below the limit of 40‰ in 2010 (it is 48.1‰). However the obtained results (measured through the AARR) place the largest part of them among the ones "on track"; only three countries (Pakistan, Tajikistan and Yemen) lag behind in this process.

At this stage, only two countries in clusters 5, 6 and 7 (Eritrea and Laos PDR) seem to be able to reach the goal in 2015. In the other countries, the AARR observed will not be sufficient to meet the MDG 4 target for 2015. In particular, while clusters 6 and 7 are characterized by U5MRs that are still very far from those required in 2015, cluster 5 and 7 stand out for the low observed AARR.

Determinants of the gaps toward MDG 4: a multivariate approach

The large disparities of child mortality levels across the LDCs and the huge differences in their chances of achieving MDG 4 induced us to try to explore the main determinants of such a situation.

Linear regression analyses were carried out considering each country as a single unit in the models. As explained in the "data and methods" section, the dependent variable is, for each country, the difference between the U5MR level required in 2010 to achieve the target and that observed in the same year. It assumes continuous values from the -121.79 of Chad to the 18.36 of Egypt (respectively the worst and the best placed country).

In the first model, only the cluster classification is considered as independent variable and the results (table 5) confirm the above described outcome, highlighting that three clusters have so far covered a very small gap with MDG 4 in respect to the others: clusters 5, 6 and 7 assume a significant ($p<0.01$) and negative coefficient compared to cluster 1 (respectively -34.0, -39.4 and -56.0), while there is no significant difference among the first four clusters.

In the second model, additional variables are added (listed in the "data and methods" section) to the cluster classification. Our aim is to highlight some health, socio-demographic and economic determinants of the heterogeneity of clusters observed so far.

The independent variables were selected according to the availability of data and the relevant literature on this topic. They were first selected in line with the conceptual framework obtained by Mosley and Chen (1984), as well as with the five theories quoted above: modernization, dependency/world-systems, economic disarticulation, developmental state and gender stratification theory (Frey and Field 2000). Their choice was aimed to consider the factors that, according to recent analysis, proved to influence child mortality levels and/or trends in a cross-country approach. In particular, the inclusion of variables regarding the health context was due to their importance recently showed by some scholars (see Agenor et al. 2006; Houweling et al. 2005; Houweling et al. 2006;

Shell et al. 2007). The determinants concerning the socio-demographic factors are based on the outcomes obtained by Amazou and Hill (2004), Masuy-Stroobant (2001), Pamuk, Fuchs and Lutz (2011), and Shell et al. (2007). The selection of the economic variables is based on the findings of relevant studies (Agenor et al. 2006; Houweling et al. 2005; Jorgeson 2004; Mayer and Sarin 2004). Many of these indicators refer to the other MDG goals in order to highlight interrelations among them, as demonstrated by Agenor et al. (2006).

As previously specified, predictors are introduced sequentially in a stepwise procedure and only statistically significant and uncorrelated ones were considered.

Moving between the two models in table 5 (respectively without and with control variables), we observe, generally speaking, an increase of the explained total variability (R-squared passed respectively from 58.7% to 68.9%) and a decrease in the value as well as in the significance of coefficients linked to the cluster classification. Thus, the variables introduced seem in part to explicate the contextual variation. However, this decrease differs among groups. In particular, the decrease of the obtained regression coefficients mainly affects cluster 7 (β passing from -56.03 to -31.20) and

Table 5. Gap between the MDG 4 target and the U5MRs. Year 2010. Linear regression models including cluster classification[(a)]

Clusters	Without control variables			With control variables[(b)]		
	Coeff.	S.E.	Sig.	Coeff.	S.E.	Sig.
1	0.00	-	-	0.00	-	-
2	-3.86	8.2	ns	-0.88	8.0	ns
3	-1.49	8.3	ns	-0.51	7.9	ns
4	-0.73	8.7	ns	-0.55	9.2	ns
5	-34.03	10.8	***	-30.99	11.5	***
6	-39.41	8.9	***	-20.84	11.3	*
7	-56.03	7.9	***	-31.20	11.1	***

(a) Two-tailed tests: * p<.10; ** p<.05; *** p<.01. R-squared equals respectively to 58.7% and 68.9%. Constant term equals respectively to 1.05 and -74.3.
(b) Control variables: population living below US$1.25 a day, primary school net enrolment, gender parity index in secondary school enrolment, antenatal care, immunization coverage against measles among 1-year-olds, density of physicians.
Source: our elaborations on United Nations (2013a), World Health Organization (2013), UNICEF (2013), UNDP (2013) and World Bank (2013) data

cluster 6 (β from -39.41 to -20.84), while it slightly concerns cluster 5 (β from -34.03 to -30.99). Therefore, we argue that, despite losing strength if we consider the "distal" predictors, the mortality patterns represented through the "intrinsic" variables included in the cluster classification act together with the latter in determining the disadvantages of the clusters that are most behind schedule in reaching MDG 4.

Table 6 excludes the cluster classification and shows only the other significant predictors. To clarify the degree to which these determinants impact on child survival across nations and to define their relative importance between countries, following also the literature (among others, Schell et al. 2007), it seemed useful to highlight in a separate model their impact on the dependent variable, not considering the role played by the cluster classification[3].

[3] The small number of the significant variables is a common factor to many studies (see "theoretical background" section) on childhood mortality in LDCs, which use macro data and consider the countries as statistic units. Being aware of the necessity of completing such an approach with the help of individual data, we highlight that the previously described determinants should be interpreted in a general sense, that is to say as indicative of sectors of strategic importance in reaching the target.

The results obtained show that the only determinant which acts negatively on the dependent variable corresponds to the quota of population living below US$1.25 a day (β: -0.23). It underlines the significant impact exerted by the incidence of extreme poverty on child mortality. This result is coherent with the approach used by Mosely and Chen (1984), which shows the role played by wealth on child survival levels. In addition, confirming the hypothesis of developmental state theory, it supports the influence that the redistributive efforts by a government can have on the possibility of reaching MDG 4. Our result is similar to that of Anand and Ravallion (1993) and Schell et al. (2007), which found that poverty spread is a significant predictor of health, and that it is more important than is absolute national income (or GNI per capita) in determining child survival. Last, since the target of MDG 1 is to eradicate extreme poverty and hunger, it is logical to conclude that reaching that goal will help countries to achieve MDG 4 as well.

The achievement of universal primary education relates to MDG 2, but it also affects MDG 4. Confirming this, multivariate analysis estimates a positive coefficient of total primary school net enrolment rate (β: 0.35). Such results confirm the findings that are emerging from the literature (United Nations Millennium Project 2005b) which show that in many LDCs the fastest improvements are taking place in countries where levels of education for boys and girls have increased the most.

Considering female education, the gender parity index in secondary school enrolment is directly linked with the dependent variable (β: 0.63). This outcome is consistent with those of Caldwell (Caldwell 1989; Caldwell and Caldwell 1985) who, as previously recalled, demonstrated the extraordinary stability of the relationship between maternal education and child survival across the different continents. Similarly, our results appear to corroborate Mosley and Chen's definition of mothers' level of education as a prominent determinant of child mortality levels. Moreover, our results uphold numerous studies that support a strong positive effect of higher maternal education on child health (Houweling et al. 2005; Pamuk, Fuchs, and Lutz 2011) and show that secondary education is the strongest predictor of infant mortality rates (Jorgenson 2004). There is also an evident link between these findings and the insights of gender stratification theory, which reveal that high female education levels are associated with increased overall women's autonomy, and support the idea that inequalities between women and men have large costs in terms of child mortality (Kravdal 2004). Finally, our result illustrates that promoting gender equality, which is the aim of MDG 3, and improving the educational and cultural status of women will lead to a substantial decline of child mortality.

Antenatal care coverage (that is, the quota of women attended at least once during pregnancy by skilled health personnel) shows a very significant effect on the dependent variable; this predictor assumes the highest coefficient in the model (β: 0.73). This aspect confirms the importance, already evidenced by Mosley and Chen, of reproductive health in determining favorable results for child survival. Furthermore, the presence of this predictor supports the close link between the improvements towards MDG 4 and the efforts in favor of maternal health-care recalled by MDG 5.

In enhancing the possibility each country has to reach MDG 4, an important role is also played by the immunization coverage against measles for children who are under one year old (β: 0.55). This outcome confirms that (as shown by previous research) through increased routine immunization coverage and large-scale immunization campaigns many LDCs have made the most progress, although they remain fragile (UNICEF 2012; UNICEF, WHO, World Bank and United Nations Population Division 2007). The need to reduce measles-related mortality cases is also in line with MDG 6 (the target aimed to combat HIV/AIDS, malaria and other diseases). A last determinant which

has a direct but less significant relation on the dependent variable is the density of physicians, which may be considered a useful indicator of sanitary system conditions in each country (β: 0.36). Also in this case the association of a scarce access to health services with high neonatal mortality is consistent with the findings of recent analysis (UNICEF, WHO, World Bank and United Nations Population Division 2007). Immunization coverage and the density of physicians have been considered as important predictors of survival levels. Mosley and Chen included both the so-called "personal illness control" (that comprises immunization) among the proximate determinants of child mortality, and health system availability among the community-level variables that act on survival of children. Referring to the developmental state theory, the presence of the immunization coverage levels and of the density of physicians among the determinants of our model confirms that the governments which are more engaged in improving the well-being of the population can obtain gains in the fight against childhood mortality. Furthermore, our finding seems to be consistent with those emerging from other research (Houweling et al. 2006; Schell et al. 2007), that demonstrate that the available crude macro measurements of public health sector spending do not have an independent effect on child survival, and that investments in health systems can have such consequence if services are delivered effectively.

Table 6. Gap between the MDG 4 target and the U5MRs. Year 2010. Linear regression model excluding cluster classification[(a)]

Variables	Coeff.	S.E.	Sig.
Population living below US$1.25 a day (%), 2002-10	-0.23	0.1	**
Primary school net enrolment/ attendance (%), total, 2003-08	0.35	0.2	*
Gender parity index in secondary school enrolment, 2009	0.63	0.2	***
Antenatal care[(b)], 2000-07	0.73	0.2	***
Immunization coverage among 1-year-olds, measles (%), 2009	0.55	0.2	***
Density of physicians (per 10,000 population), 2000-07	0.36	0.2	*

(a) Two-tailed tests: * p<.10; ** p<.05; *** p<.01. R-squared equals to 58.5% and constant term equals to -88.7.
(b) Percentage of women attended to at least once during pregnancy by skilled health personnel.
Source: our elaborations on United Nations (2013a), World Health Organization (2013), UNICEF (2013), UNDP (2013) and World Bank (2013) data

Conclusion

The results emerging in this article highlight the persistence of huge disparities in levels of child mortality worldwide. In particular, high values of U5MRs still characterize the dramatic scenario of sub-Saharan Africa today. As a consequence, our estimates of the chances each country has to reach MDG 4 confirmed that among the 50 countries defined as not "on track", 42 are in sub-Saharan Africa. The slow pace or the lack of improvements in this region reflects the consequences of the HIV/AIDS epidemic, social instability and armed conflict that still affect many countries.

In the countries not "on track", dramatic, effective, prompt and specific measures, along with demographic and socio-economic development policies are required to achieve MDG 4. These are particularly necessary if we think of the heavy repercussions that the recent global economic crisis is having on the living conditions of the most disadvantaged populations. The possible measures to be taken can be divided into at least two fields of action.

The aim of the first of these should be to act on the factors revealed by the different patterns of mortality that characterize the observed countries, on which our article has shed light. In fact, our analyses both confirmed the influence performed by the "intrinsic" causes of the largest part of

childhood deaths (e.g. communicable diseases and the most common exogenous factors) in the most disadvantaged clusters of countries, and the great usefulness to realize and implement interventions that can prevent them or/and can properly treat them. In particular, the majority of children who die could be saved by simple and, for the most part, low-cost, measures, such as skilled attendants at childbirth, immunization, proper nutrition, vitamin A supplementation, rehydration, vaccines, antibiotics and bed nets. Moreover, it is essential to make a specific effort to reduce the deaths that are the most difficult to eradicate: those which occur during the first weeks of life.

The second field of action should regard the distal determinants which significantly influence the probability of reaching the target, carrying out development policies that act on the health, socio-demographic and economic contexts.

Our results demonstrate that in order to reach MDG 4 efficient health systems that can ensure an effective availability of antenatal care and immunization, and adequate skilled human resources are required. Therefore, in line with other research (e.g. Schell et al. 2007) it can be concluded that health systems need to be more accessible, and investments in them must use sustainable and culturally sensitive forms of service delivery, since many of the successful interventions depend largely on the behavior of mothers and families.

Our results show as well the importance of educational improvements among population to enhance living condition and children health (Cohen and Soto 2007). Similarly, we demonstrated that investing in female education might be one of the most sensitive interventions to carry out. As previously recalled, because of the mother's role in her own care during pregnancy and the care of her child, improvements in her educational level can increase her skills in healthcare practices, with a positive consequence on survival in the first years of life.

Another relevant item of evidence concerns the direct relationship between extreme poverty spread and the remaining gap toward MDG 4. It was already demonstrated that poorer population groups within LDCs systematically exhibit higher child mortality than richer ones (Houweling et al. 2005; United Nations Millennium Project 2005b). Therefore, while much has been written about the deleterious effects of direct monetary aid on the development of indigenous capacities through inducing passivity and encouraging corruption (Pamuk et al. 2011), investments specifically targeted at bringing populations out of poverty by their own means can be defined as crucial in terms of reducing child mortality. Achieving this objective demands an improvement in services that aim to enhance the economic conditions of those who need them most.

Moreover, the close linkage found between the interventions to be implemented to reach MDG 4 and most of the remaining seven MDGs confirms the necessity of initiating a global political action plan of development.

Are the most disadvantaged countries the only responsible for their handicap in the fight against under-five mortality? Responsible science requires an answer to that question. Defining a country as being a "low performer" while it is doing its best to reach the target could be disempowering. In addition, some of the "donor countries" are also dangerously not "on track". In fact, while the Millennium Development Goal for official development assistance (ODA) should be on average 0.70% of gross national product, the average amount actually allocated in 2010 was only 0.32% (OECD 2012). Seven out of the twenty three most developed countries are below this level: Portugal (0.29%), New Zealand (0.26%), the United States of America (0.20%), Japan (0.20%), Greece

(0.17%), Italy (0.15%) and South Korea (0.12%). Despite apparent increases in the amount of ODA since the start of the MDGs process, it is very unlikely that this target will be reached by 2015, and the current economic crisis that has worsened the situation of many rich countries. Therefore, although a large number of developed countries are acting correctly, some of them could be seen as being “responsible” for failing to meet the MDG 4 target.

Our research shows the enormous job that remains to be done to reach the MDG 4 target by 2015. In addition to development interventions and financial aids, stronger effort to advance knowledge of the recent dynamics and main characteristics of under-five mortality must be made. In this perspective, we hope that this article could be a useful step in the research on this topic.

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