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Child Survival Progress in 194 Countries, 1990-2015

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Abstract

This paper analyses the progress towards child survival in the world during the period 1990 through 2015 on the basis of the estimates of under-five mortality rate prepared by the United Nations Inter-Agency Group on Child Mortality Estimation. The analysis reveals that in more than two-third countries of the world, the target of reducing the under-five mortality rate by two-third during 1990-2015 could not be achieved and there are countries where the under-five mortality rate increased instead decreased. A decomposition of the decrease of 6.8 million child deaths in 2015 as compared to the number of child deaths in 1990 suggests that this decrease may be attributed to both decrease in the number of live births as the result of the decrease in the birth rate and increase in the number of survivors as the result of the decrease in the probability of death during childhood. The analysis suggests that in most of the countries of the world, the commitment made towards child survival by endorsing the United Nations Millennium Declaration could not be followed up by concrete efforts at the national level.

Child Survival Progress in 194 Countries,1990-2015

Introduction

The Millennium Development Goals (MDGs) set by the United Nations in 2000 as part of the United Nations Millennium Development Agenda have been the yardstick for measuring and monitoring the global progress towards addressing different forms of extreme poverty (United Nations, 2000). These Goals have also been perceived as basic human rights. One of these Goals (MDG-4) is directed towards reducing child mortality with the target of reducing the under-five mortality rate (*U5MR*) by two-third between 1990 and 2015. The 2030 Sustainable Development Agenda of the United Nations (United Nations, 2015) also targets, among other, ending premature death of newborns and children below five years of age with all countries aiming to reduce neonatal mortality to at least as low as 12 neonatal deaths for every 1000 live births and the under-five mortality rate to at least as low as 25 under-five deaths for every 1000 live births by the year 2030 (United Nations, 2016).

Following the United Nations Millennium Development Agenda, were several analyses were carried out to track the trend in child mortality (Bhutta et al, 2010; Rajaratnam et al, 2010; You et al, 2010; Lozano et al, 2011). These and many other similar studies observed that the progress towards reducing child mortality had been substantially slower than the target required to achieve MDG-4 and stressed that intensive monitoring was needed to accelerate the progress (Lozano et al, 2011). A major limitation of these studies was that nationally representative high-quality data on under-five mortality was available at regular time intervals from civil registration system for only about 60 countries (You et al, 2015). For rest of the countries, the evidence depended on data from population censuses, household surveys, and sample registration systems. To overcome this limitation, the United Nations Inter-agency Group for Child Mortality Estimation, formed in 2004, has prepared consistent and internationally comparable country estimates of under-five mortality rate (*U5MR*), infant mortality rate (*IMR*) and neonatal mortality rate (*NMR*) along with estimates of total number of under-five deaths, infant deaths and neonatal deaths. Estimates prepared by UN IGME are updated annually after reviewing newly available data and assessing data quality. A report on the levels and trends in child mortality based on UN IGME estimates (UNICEF, 2015) has observed that major progress has been made in the world to reducing the *U5MR* and the pace of decrease appears to have accelerated after 2000 resulting in saving lives of millions of children below five years of age. The report has, however, concluded that the target of reducing *U5MR* by two-third between 1990 and 2015 could not be achieved and there is little possibility that this target could be achieved before the year 2026. Estimates prepared by UN IGME also suggest that concerted efforts are needed to avoid preventable deaths in children below five years of age in the coming years and to accelerate progress in improving child survival further (You et al, 2015). It is obvious that securing survival of children below five years of age still remains a challenging development concern for the world. The 2030 Sustainable Development Agenda recognises this challenge by setting specific targets in terms of the reduction in the under-five mortality rate and the neonatal mortality rate (United Nations, 2016).

The decrease in under-five mortality, it may be emphasised, is contingent upon the decrease in the risk of death during the neonatal period, the post-neonatal period and during 1-4 years of life. The relative contribution of neonatal mortality, post-neonatal mortality and mortality during 1-4 years of life on the under-five mortality is argued to depend upon the level of under-five mortality. It is well-known that as under-five mortality decreases, more and more under-five deaths get concentrated in infancy and in the neonatal period. During the neonatal period, more than 85 per cent of the deaths are due to just four causes - prematurity, birth asphyxia, sepsis and congenital anomalies. On the other hand, almost 60 per cent deaths during the post-neonatal period are due to diarrhoea, acute respiratory infections, malaria and injuries whereas main causes of death during 1-4 years of life are accidents (unintended injuries). This means that interventions required for preventing neonatal deaths are essentially different from those required for preventing either post-neonatal deaths or deaths in children aged 1-4 years. This also means that reduction in the risk of death during the first five years of life should be analysed in the context of the reduction in the risk of death during the neonatal period, during the post-neonatal period and during 1-4 years of life.

It is also well-known that at a given level of under-five mortality, the total number of under-five deaths are determined by the size of the population and the level of fertility. An increase in population size results in an increase in the number of under-five deaths even if there is no change in fertility and under-five mortality. Similarly, a decrease in fertility leads to a decrease in the number of under-five deaths even if population size and the risk of death during the first five years of life remain unchanged. This means that any analysis of the change in the number of under-five deaths should also take into account the change in the population size and the change in the level of fertility in addition to the change in the risk of death during the first five years of life which is determined by the risk of death during neonatal and post-neonatal period, and during 1-4 years of life.

The present paper has three objectives. The first objective is to analyse the country progress towards MDG-4 using UN IGME estimates. The second objective is to analyse how has the change in neonatal mortality, post-neonatal mortality and mortality during 1-4 years of life during 1990 through 2015 contributed to the change in under-five mortality. The third objective is to analyse how the change in the number of under-five deaths during 1990-2015 has been influenced by population growth and fertility transition in addition to the change in neonatal and post-neonatal mortality and mortality during 1-4 years of life. The analysis contributes to understanding the transition path followed by different countries towards MDG-4 and in avoiding preventable under-five deaths.

The paper is organised as follows. The next section describes the analytical framework used for the analysis. We use a decomposition framework for analysing the relative contribution of population growth, fertility transition and reduction in under-five mortality to the reduction in the number of under-five deaths. We also use the variance decomposition framework to analyse how inter-country variation in the reduction in under-five deaths is determined by the inter-country variation in population growth, fertility transition and transition in under-five mortality. Section three described the data used in the analysis. The paper is based primarily on the estimates of neonatal, infant and under-five mortality UN IGME for 194 countries for different years of the period 1990 through 2015. Section four presents an overview of variation and trend in child mortality countries. Section five presents the results of the analysis while the last section summarises the main conclusions and discusses their policy and programme implications.

Data

The analysis uses consistent and internationally comparable estimates of under-five mortality rate (*U5MR*), infant mortality rate (*IMR*), neonatal mortality rate (*NMR*) and total number of under-five deaths, infant deaths and neonatal deaths prepared by UNIGME for 194 countries of the world for different years of the period 1990-2015 (UNICEF, 2015). The methodology adopted by UNIGME for preparing these estimates are given elsewhere (UNICEF, 2015). In addition, the paper also uses annual estimates of the population of each country prepared by United Nations Population Division (United Nations, 2015a). Based on these estimates, estimates of post neonatal mortality rate (*PNMR*), mortality rate in the age group 1-4 years (*CMR*), birth rate (*BR*) and total number of live births for different years of the period 1990-2015 have been calculated for each of the 194 countries along with estimates for the world and for its major development regions.

Methodology

Let

$q_u = U5MR/1000$

$q_n = NMR/1000$

$q_p = PNMR/1000$ and

$q_c = CMR/1000$,

then

$1\text{-}q_u = (1\text{-}q_n)*(1\text{-}q_p)*(1\text{-}q_c)$

or

$$p_u = p_n * p_p * p_c \quad (1)$$

where p_u is the survival probability during the first five years of life, p_n is the survival probability during the neonatal period, p_p is the survival probability during the post-neonatal period and p_c is the survival probability during 1-4 years of life. The change in p_u over time may now be decomposed as

$$\ln\left(\frac{p_u^2}{p_u^1}\right) = \ln\left(\frac{p_n^2}{p_n^1}\right) + \ln\left(\frac{p_p^2}{p_p^1}\right) + \ln\left(\frac{p_c^2}{p_c^1}\right)$$

or

$$\partial p_u = \partial p_n + \partial p_p + \partial p_c \quad (2)$$

Equation (2) is true by definition and applies to every country so that the naive regression or correlation approaches, which ignore the sum constraint, are potentially problematic in analysing the relative contribution of the inter-country variation in the change in ∂p_n, ∂p_p and ∂p_c to the inter-country variation in the change in ∂p_u. An alternative approach (Poorter and van der Werf, 1998; Wright and Westoby, 2001) is to decompose the inter-country variance in ∂p_u as

$$\begin{aligned} Var(\partial p_u) = \; & Var(\partial p_n) + Cov(\partial p_n, \partial p_p) + Cov(\partial p_n, \partial p_c) + \\ & Var(\partial p_p) + Cov(\partial p_n, \partial p_p) + Cov(\partial p_p, \partial p_c) + \\ & Var(\partial p_c) + Cov(\partial p_c, \partial p_n) + Cov(\partial p_n, \partial p_c) \end{aligned} \quad (3)$$

where *Var* denotes the variance and *Cov* denotes the covariance. The relative contribution of the inter-country variance in the change in ∂p_n, ∂p_p and ∂p_c to the inter-country variation in the change in ∂p_u may now be obtained as

$$1 = C(\partial p_n) + C(\partial p_p) + C(\partial p_c) \quad (4)$$

where

$$C(\partial p_n) = \frac{Var(\partial p_n) + Cov(\partial p_n, \partial p_p) + Cov(\partial p_n, \partial p_c)}{Var(\partial p_u)}$$

$$C(\partial p_p) = \frac{Var(\partial p_p) + Cov(\partial p_p, \partial p_n) + Cov(\partial p_p, \partial p_c)}{Var(\partial p_u)}$$

$$C(\partial p_c) = \frac{Var(\partial p_{nc}) + Cov(\partial p_c, \partial p_n) + Cov(\partial p_c, \partial p_p)}{Var(\partial p_u)}$$

There are ways a component of ∂p_u could make a small contribution to the variation in ∂p_u. First the component is not variable across countries, and so the variance and covariance terms in equation (4) are all small. Second, the component is variable, but the covariance terms are negative and so the sum of the variance and covariance terms is small. In the second case, equation (4) may not reflect the true importance of the variance in ∂p_n or ∂p_p or ∂p_c in explaining the variance in ∂p_u. This problem may be addressed by using absolute values of the covariance terms instead of their actual values (Horvitz et al, 1997; Rees et al, 2010: Rees et al, 1996) so that the importance of the inter-country variance in ∂p_n, ∂p_p and ∂p_c to the inter-country variance in ∂p_u may be obtained as

$$1 = I(\partial p_n) + I(\partial p_p) + I(\partial p_c)$$

$$I(\partial p_n) = \frac{Var(\partial p_n) + |Cov(\partial p_n, \partial p_p)| + |Cov(\partial p_n, \partial p_c)|}{T}$$

$$I(\partial p_p) = \frac{Var(\partial p_p) + |Cov(\partial p_n, \partial p_p)| + |Cov(\partial p_p, \partial p_c)|}{T} \qquad (5)$$

$$I(\partial p_c) = \frac{Var(\partial p_c) + |Cov(\partial p_n, \partial p_c)| + |Cov(\partial p_p, \partial p_c)|}{T}$$

where the normalizing constant T is the sum of the absolute values of the terms on the right-hand side of equation (4) and is different from $Var(\partial p_u)$. Equation (5) explicitly allows for the fact that the change p_u is the the weighted sum of the change in p_n, p_p and p_c. It permits to explore the relative importance of the change in the risk of death during the neonatal, post-neonatal period and during 1-4 years of life to the change in the risk of death during the first five years of life.

Equation (2) decomposes the relative change in the probability of survival during the first five years of life. Following Kim and Strabino (1984), it is also possible to decompose the absolute change in the probability of survival during the first five years of life (∇p_u) in the following manner:

$$\nabla p_u = p_u^2 - p_u^1 = (p_n^2 * p_p^2 * p_c^2) - (p_n^1 * p_p^1 * p_c^1) \tag{6}$$

$$\begin{aligned}\nabla p_u = {} & [(p_n^2 - p_n^1) * p_p^1 * p_c^1] + [p_n^1 * (p_p^2 - p_p^1) * p_c^1] + \\ & [p_n^1 * p_p^1 * (p_c^2 - p_c^1)] + [(p_n^2 - p_n^1) * (p_p^2 - p_p^1) * p_c^1] + \\ & [(p_n^2 - p_n^1) * p_p^1 * (p_c^2 - p_c^1)] + \\ & [p_n^1 * (p_p^2 - p_p^1) * (p_c^2 - p_c^1)] + \\ & [(p_n^2 - p_n^1) * (p_p^2 - p_p^1) * (p_c^2 - p_c^1)] \\ \nabla p_u = {} & A + B + C + AB + AC + BC + ABC\end{aligned} \tag{7}$$

The contribution of the absolute change in p_n, p_p and p_c to the absolute change in p_u can now be obtained by distributing the interaction effects to individual components according to Goldfield's rule of distributing interaction effects equally among the participating components (Durand, 1948). The absolute change in p_u can thus be decomposed as

$$\begin{aligned}\nabla p_u &= dp_n + dp_p + dp_c \\ dp_n &= A + (AB + AC)/2 + ABC/3 \\ dp_p &= B + (AB + BC)/2 + ABC/3 \\ dp_c &= C + (AC + BC)/2 + ABC/3\end{aligned} \tag{8}$$

Following the same approach, if *P* denotes population size and *BR* birth rate so that $b = (BR/1000)$ and $L = P*b$ is the total number of live births, then the relative change in the total number of survivors *S* during the first five years can be decomposed into the relative change in population (*P*), birth rate (*b*), survival probability during the neonatal period (p_n), during the post-neonatal period (p_p) and during 1-4 years of life (p_c) in the following manner:

$$\ln\left(\frac{S^2}{S^1}\right) = \ln\left(\frac{P^2}{P^1}\right) + \ln\left(\frac{b^2}{b^1}\right) + \ln\left(\frac{p_n^2}{p_n^1}\right) + \ln\left(\frac{p_p^2}{p_p^1}\right) + \ln\left(\frac{p_c^2}{p_c^1}\right)$$

or

$$\partial p_u = \partial P + \partial b + \partial p_n + \partial p_p + \partial p_c \tag{9}$$

On the other hand, the absolute change in the total number of survivors during the first five years can be decomposed into the absolute change in the population size, the absolute change in the birth rate and the absolute change in the survival probability during neonatal and post neon-natal period and during 1-4 years of life as follows:

$$
\begin{aligned}
\nabla S &= S^2 - S^1 = (P^2 * b^2 * p_u^2) - (P^1 * b^1 * p_u^1) \\
\nabla S &= (P^2 * b^2 * p_n^2 * p_p^2 * p_c^2) - (P^1 * b^1 * p_n^1 * p_p^1 * p_c^1) \\
&= A + B + C + D + E + \\
&\quad AB + AC + AD + AE + BC + BD + BE + \\
&\quad CD + CE + DE + ABC + ABD + ABE + \\
&\quad ACD + ACE + ADE + BCD + BCE + \\
&\quad BDE + CDE + ABCD + ABCE + ABDE + \\
&\quad ACDE + BCDE + ABCDE \\
\nabla S &= dP + db + dp_n + dp_p + dp_c
\end{aligned} \qquad (10)
$$

If *D* denotes the total number of under-five deaths, then the change over time in the total number of survivors during the first five years of life may also be expressed as

$$
\begin{aligned}
S^2 - S^1 &= (L^2 - D^2) - (L^1 - D^1) = (L^2 - L^1) - (D^2 - D^1) \\
\nabla S &= \nabla L - \nabla D
\end{aligned} \qquad (11)
$$

Also

$$\nabla L = L^2 - L^1 = P^2 * b^2 - P^1 * b^1 \qquad (12)$$

or

$$\nabla L = d'P + d'b \qquad (13)$$

Notice that *d'P* and *d'b* in equation (13) are different from *dP* and *db* in equation (10). Now using (10), (11) and (13)

$$
\begin{aligned}
\nabla D &= \nabla L - \nabla S \\
&= d'P + d'b - (dP + db + dp_n + dp_p + dp_c)
\end{aligned} \qquad (14)
$$

Also

$$
\begin{aligned}
\nabla D &= D^2 - D^1 = (L^2 - L^1) - (S^2 - S^1) \\
&= (P^2 * b^2 - P^1 * b^1) \\
&\quad -(P^2 * b^2 * p_n^2 * p_p^2 * p_c^2 - P^1 * b^1 * p_n^1 * p_p^1 * p_c^1) \\
&= P^2 * b^2 * (1 - p_n^2 * p_p^2 * p_c^2) - P^1 * b^1 * (1 - p_n^1 * p_p^1 * p_c^1) \\
&= P^2 * b^2 * q_u^2 - P^1 * b^1 * q_u^1 \\
&= A + B + C + AB + AC + BC + ABC \\
&= dP + db + dq_u
\end{aligned} \qquad (15)
$$

Global Transition in Child Mortality

Estimates prepared by the UN IGME suggest that *U5MR* in the world decreased by 53 per cent between 1990 and 2015 which means that the world could not achieve MDG-4 (Table 1). In other words, efforts to reduce child mortality in the world fell short of the expectations laid down in the Millennium Development Agenda of the United Nations. It is also evident from table 1 that none of the three contributors to *U5MR* - *NMR*, *PNMR* and *CMR* - decreased by at least two-third during the period under reference. However, the decrease has been relatively the least rapid in *NMR* but the most rapid in *CMR*. Moreover, MDG-4 could also not be achieved in any of the three major development regions of the world, although, the decrease in *U5MR* has relatively been the most rapid in the developed region but the least rapid in the developing region. In all the development regions, the decrease has relatively been the most rapid in *CMR* but the least rapid in *NMR*. The decrease in *NMR* has relatively been the most rapid in the developed region but the least rapid in the least developed region of the world. On the other hand, the decrease in *PNMR* has relatively been the most rapid again in the developed region but the least rapid in the developing region whereas the decrease in *CMR* has relatively been the most rapid in the least developed region but the least rapid in the developed region. In fact, it is only *CMR* only in the least developed region which decreased by more than two-third during 1990-2015.

UN IGME estimates also suggest that *U5MR* did not decrease in all the 194 countries. There are three countries - Niue, Lesotho and Dominica - where *U5MR* increased, instead decreased, during the period under reference. Similarly, *NMR*, *PNMR* and *CMR* also did not decrease in all the 194 countries. The *NMR* increased in two countries - Dominica and Zimbabwe; the *PNMR* increased in six countries - Sam Marino, Brunei, Seychelles, Niue, Fiji, and Lesotho - and the *CMR* increased in two countries - Malta and Lesotho - during the period under reference. At the same time, there was no neonatal death in Niue in 1990 and again in 2015. Simialrly, there was no death of children aged 1-4 years in 1990 as well as in 2015 in five countries - Sam Marino, Andora, Monaco and Niue.

On the other hand, among the 191 countries where *U5MR* decreased during the period 1990-2015, the pace of decrease varied widely (Table 2). There are only 60 (30.9 per cent) countries - 17 developed, 30 developing; and 13 least developed - where *U5MR* decreased by at least two-third during 1990-2015. This means that in 134 countries, MDG-4 could not be achieved. The decrease in *U5MR* has been the most rapid in Maldives which is the only country where *U5MR* decreased by more than 90 per cent between 1990 and 2015. Besides Maldives, there are only three countries - Macedonia, Estonia and Turkey - where *U5MR* decreased by 80-90 per cent during the period under reference. By contrast, the decrease in *U5MR* has been the least rapid in Zimbabwe which is the only country where *U5MR* decreased by less than 10 per cent between 1990 and 2015. In Brunei, Seychelles and Swaziland also, the decrease in *U5MR* has been very slow. Among the developed countries, the decrease in *U5MR* was the slowest in United States of America but the fastest in Macedonia. Among the developing countries, the decrease was the slowest in Zimbabwe but the fastest in Maldives and, among the least developed countries, the decrease was the fastest in Bhutan but the slowest in Vanuato.

The goal of reducing child mortality by at least two-third from the level that prevailed in 1990 could not be met in the world and in its three development regions in terms of *NMR*, *PNMR* and *CMR* also. The *NMR* decreased by two-third in only 35 countries - 19 developed and 16 developing. There is no least developed country where the *NMR* decreased by at least two-third between 1990 and 2015. On the other hand, the *PNMR* decreased by at least two-third in 77 countries - 27 developed; 34 developing; and 16 least developed - whereas the *CMR* decreased by at least by two-third in 84 countries which include 16 developed; 41 developing; and 27 least developed countries.

The decrease in *U5MR* as well as in *NMR*, *PNMR* and *CMR* during 1990-2015 has not been found to be related to the level of child mortality that prevailed in 1990. A comparison of the median decrease in *U5MR* across the three development regions of the world suggests that the decrease in *U5MR* between 1990 and 2015 was the most rapid in the developed countries but the least rapid in the developing countries. The level of child mortality was the lowest in the developed countries but the highest in the least developed countries in 1990. The cumulative distribution of the decrease in *U5MR* in developed, developing and the least developed countries also confirms that *U5MR* decreased more rapidly in the developed countries as compared to the developing and the least developed countries. Similarly, the decrease in *NMR* and *PNMR* has also been found to be more rapid in the developed countries as compared to the developing and the least developed countries. However, the decrease in the *CMR* during 1990-2015 has been found to be the most rapid in the least developed countries where the *CMR* was the highest in 1990. The exploratory data analysis suggests that there are two outlier countries - Brunei and Zimbabwe - where the decrease in *U5MR* during 1990-2015 was exceptionally slow as compared to other countries. Similarly, the decrease in the *NMR* has been found to be exceptionally slow in Zimbabwe whereas the decrease in the *PNMR* has been found to be exceptionally slow in nine countries - Mauritania, Brunei, San Marino, Seychelles, Barbados, Tonga, Bahrain, Grenada and Fiji. Lastly, the decrease in *CMR* during 1990-2015 has been found to be exceptionally slow in six countries - Zimbabwe, Swaziland, Andora, San Marino, Monaco and Malta.

Decomposition of the Change in *U5MR*

Table 3 decomposes the change in *U5MR* during 1990-2015 into the change in *NMR*, *PNMR* and *CMR* in conjunction with equation (2). The change in *NMR*, *PNMR* and *CMR* appears to have contributed almost equally to the change in *U5MR* in the world as a whole during the period under reference. The relative contribution of the change in *NMR*, *PNMR* and *CMR* to the change in *U5MR* has however been different in different development regions. In the developed countries of the world, the change in *U5MR* has mainly been the result of the change in *NMR* whereas the change in *U5MR* in the least developed countries may be attributed primarily to the change in *CMR*. In the developing countries, on the other hand, the contribution of the change in *NMR* has been substantially higher than that of *PNMR* whereas, in the least developed countries, the contribution of the change in *NMR* to the change in *U5MR* has relatively been the smallest relative to the contribution of the change in *PNMR* and *CMR*.

The change in *U5MR* as well as in *NMR*, *PNMR* and *CMR* has varied widely across 194 countries. Table 4 decomposes the inter-country variance in the change in p_u into inter-country variance in the change in p_n, p_p and p_c on the basis of equation (4). More than half of the inter-country variance in the change in p_u in the world may be accounted by the inter-country variance in the change in p_c while the inter-country variance in the change in p_n accounts for less than 15 per cent of the inter-country variance in the change in p_u. In the developed countries, however, the inter-country variance in the change in p_u is determined almost equally by the inter-country variance in the change in p_p and the inter-country variance in the change in p_n. The contribution of the inter-country variance in the change in p_c to the inter-country variance in p_u has not found to be large in these countries probably and so obviously because . In the developing countries, the main contributors to the inter-country variance in the change in p_u has been the inter-country variance in the change in p_p and p_c. The contribution of the inter-country variance in the change in p_n to the inter-country variance in the change in p_u has not been found to be substantial in these countries. On the other hand, in the least developed countries, the inter-country variation in the change in p_c is the most important determinant of the inter-country variation in the change in p_u whereas the contribution of the inter-country variation in the change in p_n is found to be the least important determinant of the inter-country variation in the change in p_u. It is obvious from table 5 that the path followed by developed, developing and the least developed countries of the world towards MDG-4 has essentially been different. This is expected as child mortality levels vary widely across the countries depending upon the stage of social and economic development in the country.

Distance to MDG-4

Although, child mortality estimates prepared by UN IGME suggest that *U5MR* has decreased in all but three countries, yet, these estimates make it clear that the decrease in child mortality has not been large enough to achieve the MDG-4 either globally or separately in its three major development regions. The reason is that MDG-4 could not be achieved in 132 countries which include not only the least developed countries of the world but also the developed and the developing countries. A pertinent question, therefore, is to forecast the year by when the world would be able to reduce *U5MR* by two-third from the level that prevailed in 1990 under the assumption that the trend in *U5MR* observed during 1990-2015 will continue in the coming years. The time series forecasting technique has been used for the purpose. The Expert Modeller option of the Forecasting Routine of the Statistical Package for Social Sciences (SPSS) was adopted to select the most appropriate time series model for forecasting the survival probability and hence mortality in the first five years of life. The advantage of using Expert Modeler option is that it eliminates, to a significant extent, the cumbersome trial and error process associated with the time series modeling (IBM, *no date*). The Expert Modeller automatically identifies that time series model which best fits the data. The time series forecasting exercise has been carried out for the world as well as separately for its three major development regions and for each of those 132 countries which could not reduce *U5MR* by two-third between 1990 and 2015.

Results of the time series forecasting exercise are presented in table 5. This exercise suggests that the *U5MR* in the world is likely to reduce by two-third from the level that prevailed in 1990 some times during the year 2026 or more than 10 years behind the targeted year set in MDG-4 under the assumption that the observed trend in *U5MR* during 1990-2015 will continue in the coming years. The forecasting exercise also suggests that the MDG-4 is likely to be achieved by the year 2022 in the developed and in the least developed regions of the world but, in the developing region, the MDG-4 is the most likely to be achieve by the year 2027 only. Moreover, the trend during 1990-2015 indicates that, without additional efforts, 53 countries of the world - 5 developed, 33 developing and 15 least developed - will not be able to reduce *U5MR* by two-third from the level that prevailed in 1990 even by the year 2030. In these countries, mobilisation of substantial additional efforts will be required to accelerate the pace of reduction in child mortality in the coming years so that they can achieve MDG-4 even by the year 2030. It is also evident from table 5 that only 21 of the 134 countries which could not achieve MDG-4 would be able to reduce *U5MR* by two-third by the year 2020; another 30 countries will be able to reduce *U5MR* by two-third sometimes during 2021-2025 from the level that prevailed in 1990.

Transition in the Number of Child Deaths

The estimates prepared by UN IGME suggest that total number of under-five deaths in the world decreased by around 6.804 million from around 12.75 million in 1990 to around 5.95 million in 2015 (Table 6). This decrease has been the result of both decrease in the number of live births as the result of the decrease in birth rate and increase in the number of survivors as the result of the decrease in *U5MR*. The number of live births in the world decreased by around 1.128 million between 1990 and 2015 whereas the number of survivors during the first five years of life increased by around 5.676 million survivors during this period. The proportionate decrease in the number of under-five deaths during 1990-2015 was relatively the highest in the least developed region of the world (64.7 per cent) but the lowest in the developed region (38.6 per cent) with the number of under-five deaths in the developing region reducing by around 59.1 per cent. The difference in the proportionate reduction in the number of under-five deaths across the three development regions of the world has resulted in an increase in the concentration of the global under-five deaths in the least developed countries from around 28.5 per cent in 1990 to 37.5 per cent in 2015. On the other hand, the proportion of under-five deaths in the developed countries to the total number of under-five deaths in the world decreased from 1.7 per cent in 1990 to 1.3 per cent in 2015 whereas under-five deaths in the developing countries as proportion to the total number of under-five deaths in the world decreased from 69.8 per cent in 1990 to 61.2 per cent in 2015.

Among different countries of the world, Estonia recorded the most rapid decrease in the number of under-five deaths followed by Maldives - the only two countries where the number of under-five deaths decreased by more than 90 per cent between 1990 and 2015. In addition, there are only 19 countries where the number of under-five deaths decreased by 80-90 per cent during this period. In China, the most populous country of the world, the number of under-five deaths decreased by more than 80 per cent during period under reference. By contrast, the number of under-five deaths decreased by only about 64 per cent in India, the second most populous country of the world. On the other hand, there are 14 countries where the total number of under-five deaths increased, instead decreased, during the period under reference with the increase being the most rapid in Angola where the number of under-five deaths increased by more than 38 per cent between 1990 and 2015. In Chad and Zimbabwe also, the number of under-five deaths increased by more than 30 per cent during the period under reference. Moreover, there are two countries - Niue and Monaco - where there has been no change in the number of under-five deaths in 2015 as compared to the number of under-five deaths in 1990.

Decomposition of the Change in Under-five Deaths

The change in the number of under-five deaths can be attributed to the change in the number of live births and the change in the number of survivors during the first five years of life. The change in the number of live births is determined by the change in the size of the population and the change in the birth rate. On the other hand, the change in the number of survivors is determined by the change in population size, change in the birth rate and the change in the survival probability during the first five years of life which, in turn, is determined by survival probability during the neonatal and the post-neonatal periods and during 1-4 years of life.

Table 7 decomposes the decrease in the number of under-five deaths in the world and in its major development regions between 1990-2015 into the change in population size, birth rate and the change in the number of survivors during the neonatal and the post-neonatal period and during 1-4 years of life. The number of under-five deaths in the world decreased by 6.804 million between 1990 and 2015. About 17 per cent of this decrease is attributed to the decrease in the number of live births whereas around 83 per cent of the decrease is attributed to the increase in the number of survivors during the first five years of life. The decrease in the birth rate from around 26.7 live births per 1000 population in 1990 to around 19.1 in 2015 resulted in a decrease of around 47.643 million live births in the world between 1990 and 2015. However, the world population increased from around 5276 million in 1990 to around 7310 million in 2015 which resulted in an increase in the number of live births by almost 46.515 million so that the net decrease in the number of live births between 1990 and 2015 was around 1.128 million.

The decrease in the birth rate also resulted in a decrease of 44.525 million survivors whereas the increase in population resulted in an increase of around 43.349 million survivors during the first five years of life so that the net decrease in the number of survivors in the first five years of life due to the increase in the population and the decrease in the birth rate was 1.176 million. At the same time, the decrease in mortality during the first five years of life resulted in an increase of 6.852 million in the number of survivors during the first five years so that the net increase in the number of survivors during the first five years of life was 5.676 million. The increase in the number of survivors during the neonatal period was 2.339 million, 2.071 million during the post-neonatal period, and 2.442 million during 1-4 years of life. In other words, the momentum effect of world population growth during 1990-2015 resulted in an increase of 3.160 million under-five deaths but the decrease in the birth rate resulted in a decrease of 3.112 million under-five deaths while the decrease in mortality in the first five years of life resulted in a decrease of 6.852 million under-five deaths in the world between 1990 and 2015.

Table 7 also suggests that the increase in the number of under-five deaths as the result of population growth was nearly compensated by the decrease in the number of under-five deaths as the result of the decrease in the birth rate in the world whereas the decrease in the number of under-five deaths as the result of the decrease in the birth rate more than compensated the increase in the number of under-five deaths as the result of the increase in population in the developed and the developing regions of the world. However, in the least developed region, the decrease in the number of under-five deaths as the result of the decrease in the birth rate has been substantially smaller than the increase in the number of under-five deaths as the result of the increase in population so that the decrease in the number of under-five deaths in this region of the world has been substantially smaller than the decrease attributed to the decrease in the risk of death during the first five years of life. It is obvious from table 8 that the increase in the concentration of the global under-five deaths in the least developed region of the world in 2015 as compared to that in 1990 may be attributed to slow fertility transition in this region as reflected by the decrease in the birth rate.

Estimates prepared by UN IGME also reveal that more than 76 per cent of the decrease in the under-five deaths in the world between 1990 and 2015 were confined to only seven countries - Bangladesh, Brazil, China, Ethiopia, India, Indonesia and Pakistan - with China and India, alone, accounting for more than half of the decrease in the total under of under-five deaths in the world between 1990 and 2015. On the other hand, in 14 countries - 5 developing and 9 least developed - the number of under-five deaths increased, instead decreased, accounting for an increase of 0.106 million under-five deaths. In these 14 countries, the under-five mortality increased in only two countries whereas the birth rate decreased in all the countries. This means that the increase in the number of under-five deaths in these countries has been due to the fact that the decrease in the number of live births and the increase in the number of survivors as the result of the decrease in the birth rate and the decrease in the under five mortality rate has not been able to compensate the increase in the number of live births and the increase in the number of under-five deaths as the result of the increase in population. In order to ensure a decrease in the total number of under-five deaths, it is imperative that the decrease in the number of live births and increase in the number of survivors as the result of the decrease in the birth rate and the decrease in the under-five mortality rate must be larger than the increase in the number of live births and the increase in the number of under-five deaths attributed to population increase. In other words, a certain minimum decrease in the birth rate and the under-five mortality rate is necessary to compensate for the increase in the number of live births and the number of under-five deaths as the result of the momentum effect of population growth.

The relative importance of the inter-country variation in the change in population size, birth rate and the under-five mortality rate to the inter-country variation in the change in the number of under-five deaths is shown in table 8. For the world as a whole, inter-country variation in the change in the under-five mortality rate is found to be twice as important as the inter-country variation in population change and the change in the birth rate in explaining the inter-country variation in the change in the number of under-five deaths. In the developed countries, the inter-country variation in the decrease in the number of under-five deaths is found to be very heavily influenced by the inter-country variation in the change in under-five mortality rate but that of inter-country variation in population growth has, at best, been marginal. In the least developed countries, the importance of the inter-country variation in the change in the birth rate has been found to be very low compared to that in under-five mortality rate and population change. Finally, in the developing countries, the importance of the inter-country variation in the three components to the inter- country variation in the number of under-five deaths is found to be nearly the same as that in the world as a whole. This shows that the relative importance of the inter-country variation in population change, birth rate and under five mortality rate to the inter-country variation in the change in the number of under-five deaths is different in different development regions of the world.

Conclusions

The foregoing analysis indicates that in most of the countries of the world, whether developed or developing or the least developed, the progress towards child survival during 1990-2015 has remained unsatisfactory in the context of the target set under the Millennium Development Agenda. This means that the most of the countries could not be able to mobilise resources necessary for the realisation of the commitment made by endorsing the Millennium Development Agenda. The failure of the 134 countries of the world to reduce *U5MR* by two-third between 1990 and 2015 implies that around 1.7 million deaths of children below five years of age could not be saved in the world between 1990 and 2015. These countries, apparently, lacked the political will to mobilise additional resources necessary for hastening the pace of reduction in under-five mortality. The decrease in the number of under-five deaths has particularly been slow in the least developed countries of the world not because the decrease in under-five mortality has been slow but because the transition in fertility in these countries has been slow so that the decrease in the under-five deaths as the result of the decrease in the birth rate could not compensate for the increase in the number of under-five deaths as the result of the increase in the population of these countries.

Efforts to reduce the risk of death during the first five years of life and prevent premature death of children below five years of age in the world have primarily built around the integrated management of childhood illness (IMCI) strategy developed and launched by WHO and UNICEF in 1995 and which was expanded to include neonatal care in 2003 to be renamed as integrated management of neonatal and childhood illness (IMNCI). A review of the strategy by WHO in 2016 has concluded that over a period of 20 years, the interest and funding for IMNCI have waned, implementation has proved problematic and coverage at scale could be achieved by only a few countries (WHO, 2016). The review has also observed that a holistic view of child health has been lost inside the continuum of reproductive, maternal, newborn, child and adolescent health (RMNCAH), although specific child survival interventions such as immunisation continued to be the focus of attention.

Given a high degree of variability in the pathway to child survival across the countries, it is imperative that a country specific tailored response is needed to promote child survival. Such a response is all the more important as the target set under the 2030 Sustainable Development Agenda of the United Nations has set a target of reducing the under-five mortality rate to at least as low as 25 under-five deaths per 1000 live births and the neonatal mortality rate to at least as low as 12 neonatal deaths per 1000 live births by the year 2030. Given the progress during 1990-2015, these targets are definitely ambitious. However, they can be achieved by sustaining a strong political will, investing adequately in children and evidence-based planning, programming and monitoring and evaluation of child survival action.

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Table 1
Transition in child mortality in the world and major development regions, 1990-2015

Child mortality indicators	Level		Decrease	
	1990	2015	Absolute	Proportionate (Per cent)
		World		
U5MR	90.6	42.6	48.0	53.0
NMR	36.3	19.2	17.1	47.1
PNMR	28.2	12.9	15.3	54.3
CMR	29.0	11.1	17.9	61.7
		Developed countries		
U5MR	14.8	5.9	8.9	60.1
NMR	7.7	3.2	4.5	58.4
PNMR	4.7	1.8	2.9	61.7
CMR	2.5	0.9	1.6	64.0
		Developing countries		
U5MR	84.7	37.8	46.9	55.4
NMR	37.3	18.7	18.6	49.9
PNMR	25.3	10.7	14.6	57.7
CMR	24.6	8.9	15.7	63.8
		Least developed countries		
U5MR	174.3	73.3	101.0	57.9
NMR	51.7	27.6	24.1	46.6
PNMR	60.2	24.9	35.3	58.6
CMR	73.5	22.7	50.8	69.1

Source: Author's calculations based on UN IGME estimates

Table 2

Decrease in *U5MR*, *NMR*, *PNMR* and *CMR* in 194 countries, 1990-2015.

Decrease during 1990-2015 relative to 1990	All	Developed countries	Developing countries	Least developed countries
		U5MR		
< 0	3	0	2	1
0-33 per cent	16	0	11	5
33-50 per cent	40	3	26	11
50-66 per cent	75	27	32	16
≥66 per cent	60	17	30	13
Median decrease	58.4	63.5	55.2	56.2
		NMR		
< 0	2	0	2	0
0-33 per cent	39	2	25	12
33-50 per cent	51	9	22	20
50-66 per cent	67	18	36	14
≥66 per cent	35	18	16	0
Median decrease	51.3	62.9	51.5	41.0
		PNMR		
< 0	6	1	4	1
0-33 per cent	21	0	14	7
33-50 per cent	27	5	13	9
50-66 per cent	63	14	36	13
≥66 per cent	77	27	34	16
Median decrease	62.3	68.1	57.8	59.1
		CMR		
< 0	2	1	0	1
0-33 per cent	15	5	8	2
33-50 per cent	25	6	14	5
50-66 per cent	68	19	38	11
≥66 per cent	84	16	41	27
Median decrease	63.5	62.1	62.8	70.0
N	194	47	101	46

Source: Author's calculations

Note: Median decrease is calculated for those countries only where child mortality decreased between 1990 and 2015.

Table 3

Decomposition of the change in *U5MR* into changes in *NMR*, *PNMR* and *CMR* during 1990-2015 in the world and in its major development regions

Absolute change	World	Developed countries	Developing countries	Least developed countries
Change in *U5MR*	48.0	8.8	46.9	101.0
Change in *NMR*	16.4	4.4	17.9	22.0
Change in *PNMR*	14.5	2.9	14.0	32.3
Change in *CMR*	17.1	1.5	15.0	46.7

Table 4

Decomposition of the variance in the decrease across countries in *U5MR*

Variance estimates	World	Developed countries	Developing countries	Least developed countries
Inter-country variance in ∇p_ux10^6	2617.12	61.21	1010.67	3204.04
Inter-country variance in the decrease in ∂p_n (%)	14.37	33.53	18.56	10.98
Inter-country variance in the decrease in ∂p_p (%)	33.64	46.38	41.22	30.15
Inter-country variance in the decrease in ∂p_c (%)	51.99	20.09	40.22	58.87
N	194	47	101	46

Table 5
Likely year of achieving MDG-4 by countries

Countries	World	Developed countries	Developing countries	Least developed countries
Total number of countries	194	47	101	46
Countries which achieved MDG-4 by 2015	62	19	29	14
Countries likely to achieve MDG-4 by				
2016	7	1	4	2
2017	4	2	2	0
2018	6	3	3	0
2019	0	0	0	0
2020	4	1	2	1
2021	6	3	2	1
2022	6	3	2	1
2023	3	2	1	0
2024	6	2	3	1
2025	9	3	5	1
2026	7	1	3	3
2027	7	1	3	3
2028	7	1	5	1
2029	3	0	1	2
2030	4	0	3	1
Beyond 2030	53	5	33	15
Total	132	28	72	32

Table 6
Transition in the number of under-five deaths in the world and in its major development regions

Deaths (Million)	World	Developed countries	Developing countries	Least developed countries
		1990		
Under-five deaths	12.749	0.219	8.896	3.634
Neonatal deaths	5.106	0.114	3.914	1.078
Post-neonatal deaths	3.817	0.069	2.560	1.189
Deaths 1-4 years	3.825	0.036	2.423	1.366
		2015		
Under-five deaths	5.945	0.077	3.636	2.231
Neonatal deaths	2.682	0.042	1.800	0.840
Post-neonatal deaths	1.768	0.023	1.009	0.736
Deaths 1-4 years	1.494	0.012	0.826	0.656
Number of countries	194	47	101	46

Table 7

Decomposition of the decrease in the under-five deaths in the world and major development regions, 1990-2015 (Million)

Components	World	Regions		
		Developed	Developing	Least developed
Decrease in the number of under-five deaths (∇*D*)	-6.804	-0.142	-5.260	-1.402
Decrease in the number of live births (∇*L*)	-1.128	-1.769	-8.942	9.583
Increase in the number of survivors due to decrease in *U5MR* (∇*S*)	5.676	-1.627	-3.682	10.985
Increase in the number of live births due to increase in population ()	46.515	1.249	35.472	16.141
Decrease in the number of live births due to decrease in fertility ()	-47.643	-3.018	-44.414	-6.558
Increase in survivors due to population increase (∂*P*)	43.349	1.236	33.235	14.099
Decrease in survivors due to decrease in birth rate (∂*b*)	-44.525	-2.987	-41.745	-5.776
Increase in survivors due to decrease in *NMR* (∂p_n)	2.339	0.062	1.844	0.579
Increase in survivors due to decrease in *PMR* (∂p_p)	2.071	0.040	1.438	0.852
Increase in survivors due to decrease in mortality in 1-4 years (∂p_c)	2.442	0.021	1.546	1.231
Increase in survivors due to decrease in mortality in 0-5 years	6.852	0.123	4.828	2.662

Table 8
Relative importance of population increase, fertility decrease and the decrease in under-five mortality to the inter-country variation in the number of under-five deaths

Particulars	World	Developed countries	Developing countries	Least developed countries
Inter-country variation in $I(\partial P)$	24.29	8.55	23.55	33.41
Inter-country variation in ∂b	24.48	18.09	25.14	15.96
Inter-country variation ins ∂q_u	51.24	73.36	51.31	50.62

Figure 1

Cumulative distribution of the proportionate decrease in *U5MR*, *NMR*, *PNMR* and *CMR* in developed, developing and least developed countries