Empirics of Child Survival Progress in 190 Countries:1990-2015

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Abstract

This paper analyses the progress towards child survival in 190 countries during 1990-2015 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, 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 during this period. The analysis suggests that the progress towards child survival during 1990-2015 was arrived at largely by eroding the 'soft' rock of under-five mortality or by preventing deaths due to exogenous causes of under-five mortality, especially in 1-4 years of life. Although, inter-country disparity in child survival decreased over time, yet, the speed of convergence was slow. In many countries the number of child deaths prevented as the result of the improvement in child survival probability was compensated by the increase in under-five deaths because of rapid population growth. The analysis suggests that in most of the countries, the commitment made towards child survival by endorsing the United Nations Millennium Declaration could not be followed up by concrete efforts in terms of increased investment in children. The paper calls for country specific approach to accelerating the child survival progress.

Key words
Child survival, Millennium Development Goals, Convergence, Decomposition, Child deaths

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Introduction

Child survival remains an unfinished development agenda for the world. The United Nations had set a target of reducing the under-five mortality by two-third between 1990 and 2015 as part of its Millennium Development Agenda, 2000 (United Nations, 2000). However, a recent report prepared by the United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) has concluded that, although, major progress has been made in reducing under-five mortality and the pace of decrease accelerated after 2000, yet the target set for reducing under-five mortality in the Millennium Development Agenda could not be achieved (UNICEF, 2015). Other studies have also observed that child survival progress has been slower than what was required to achieve the target set under the Millennium Development Agenda (Bhutta et al, 2010; Rajaratnam et al, 2010; You et al, 2010; Lozano et al, 2011). The slower than expected progress towards child survival has also been recognised by the United Nations in its 2030 Sustainable Development Agenda which has set specific targets in terms of 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 per 1000 live births and under-five mortality to at least as low as 25 under-five deaths for every 1000 live births by the year 2030 (United Nations, 2016). The essential difference between child survival targets set under the Millennium Development Agenda and the 2030 Sustainable Development Agenda is that the target set under the Millennium Development Agenda is defined in relative terms while the targets set under the 2030 Sustainable Development Agenda are global minimum standards - level end goals. The relativeness of the target set under the Millennium Development Agenda implies that every country, irrespective of the level, should contribute to global reduction in under-five mortality. The relativeness of the target also implies that the absolute reduction in child mortality or improvement in child survival probability in a given period depends upon the level of child mortality or survival probability at the beginning of the period – the higher the child mortality the larger the absolute reduction in child mortality required. By contrast, global minimum standards, set under the 2030 Sustainable Development Agenda, essentially mean that countries which have already achieved these standards are out of the purview of the Agenda. Estimates prepared by UN IGME suggest that 112 countries had achieved the target of under-five mortality set for the year 2030 under the 2030 Sustainable Development Agenda as early as in 2015. Similarly, 112 countries had already achieved the target for neonatal mortality set for 2030 as early as in 2015.

Reduction in the under-five mortality, it may be pointed out, is contingent upon the reduction in neonatal mortality, post-neonatal mortality and mortality in 1-4 years of life. The relative contribution of the reduction in mortality in the three age segments to the reduction in the under-five mortality varies by the level of under-five mortality. It is well known that, with the decrease in under-five mortality, more and more under-five deaths get concentrated in the neonatal period. Main causes of death during neonatal and post neonatal periods and during 1-4 years of life are also different. More than 85 per cent deaths during the neonatal period 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 accidents (unintended injuries) are main causes of death during 1-4 years of life according to the causes of death data bank maintained by the World Health Organization. The interventions required for preventing deaths during neonatal and post-neonatal periods and during

1-4 years of life, therefore, are also different. This means that the reduction in under-five mortality or the child survival progress should be analysed in terms of the reduction in neonatal and post-neonatal mortality and mortality in 1-4 years of life or, equivalently, in terms of the improvement in the survival probability during neonatal and post-neonatal periods and during 1-4 years of life. Such an analysis is important as programmes and interventions directed towards preventing under-five deaths are dependent the level of neonatal, post neonatal mortality and mortality in 1-4 years of life.

Moreover, at a given level of under-five mortality, the number of under-five deaths are also determined by the size of the population and the level of fertility also. An increase in the size of the population exerts a momentum effect and leads to an increase in the number of under-five deaths even if the rate of decrease in fertility and under-five mortality remains unchanged. Similarly, a decrease in fertility leads to a decrease in the number of under-five deaths even if there is no change in the rate of population growth and under-five mortality. The analysis of change in the number of under-five deaths, therefore, should take into the account, the change in population size and transition in fertility in addition to the change in mortality or survival probability during childhood.

The above considerations constitute the rationale for the present paper which attempts a deeper understanding of the child survival progress in 190 countries of the world during 1990-2015. These countries account for almost 99.5 per cent of the world population in 2015 as estimated by the United Nations Population Division (United Nations, 2017). The paper has three objectives. The first objective of the paper is to analyse the trend in inter-country variation in the probability of survival in the first five years of life in the context of inter-country variation in the probability of survival in 1-4 years of life and in postnatal and neonatal periods. We classify countries on the basis of the improvement in the survival probability in the first five years of life after taking into consideration the improvement in survival probability during 1-4 years of life and during post neonatal and neonatal periods. The second objective of the paper is to examine the convergence in child survival probability across countries. The convergence analysis is concerned with the level of disproportions across countries in child survival. It provides the evidence whether inter-country disparity in child survival probability has decreasing over time or not. The third objective of the paper is to analyse the relative contribution of the change in the survival probability in 1-4 years of life and in postnatal and neonatal periods to the change in the survival probability in the first five years of life. This decomposition is important as the change in the survival probability in the first five years of life is possible only through the change in the survival probability in 1-4 years of life as well as in postnatal and neonatal periods. Finally, the fourth and the last objective of the paper is to analyse the contribution of the change in population size, transition in fertility to the change in the number of under-five deaths in addition to the change in the survival probability in neonatal and post-neonatal periods and in 1-4 years of life to understand the dynamics of preventing premature child deaths in the world.

The paper is organised as follows. The next section of the paper describes the data used in the analysis. The analysis is based primarily on the estimates of the risk of death during the first five years of life; during the first year of life and during the neonatal period prepared by the United Nations Inter-Agency Group on Child Mortality Estimation (UN IGME). The third section of the paper describes the analytical framework used in the analysis while the fourth section presents an overview of child survival progress in 190 countries. Results of the convergence analysis are presented in section five while results of the decomposition analysis are presented in sections six and seven of the paper. The last section summarises main findings and discusses their relevance to accelerating child survival progress.

Data

The analysis is based on the estimates of under-five mortality rate (*U5MR*), infant mortality rate (*IMR*) and neonatal mortality rate (*NMR*) prepared by UN IGME for 198 countries of the world for different years of the period 1990-2015 along with estimates of total number of under-five, infant and neonatal deaths (UNICEF, 2017). Estimates of *U5MR*, *IMR*, and *NMR* prepared by UN IGME are actually the probability of death, respectively, in the first five years of life, in infancy and in the neonatal period expressed as per 1000 live births. The methodology adopted by UN IGME for preparing these estimates is described elsewhere (UNICEF, 2018). In addition, population estimates prepared by the United Nations Population Division for different years of the period 1990-2015 have also been used in the present analysis (United Nations, 2017).

The analysis is restricted to only 190 countries which had a population of at least 20 thousand in 2015. These include 47 developed countries; 98 developing countries and 45 least developed countries according to the classification adopted by the United Nations. Total population of these 190 countries was 7.342 billion in 2015 which was almost 99.5 per cent of the world population. The child survival experience of these 190 countries, therefore, closely reflects the child survival experience of the world.

Methodology

Let
$p_u = 1 - q_u$; $q_u = U5MR/1000$
$p_n = 1 - q_n$; $q_u = NMR/1000$, and
$p_i = 1 - q_i$; $q_u = IMR/1000$.

The probability of survival during the postnatal period, p_p, and the probability of survival during 1-4 years of life, p_c, can then be estimated as

$p_p = p_i/p_n$ and $p_c = p_u/p_i$

so that

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

Equation (1) suggests that the change in inter-country variation in p_u can be analysed in terms of the change in inter-country variation in p_c, p_p and p_n. One approach to analyse the change in the inter-country variation is the convergence analysis approach. The convergence across countries in p_u, p_n, p_p and p_c can be analysed in terms of σ-convergence and β-convergence. When inter-country dispersion in child survival probabilities decreases over time, there is σ-convergence which implies that the inter-country inequality in child survival is decreasing over time. When the partial correlation between the increase in the child survival probability in a given period of time and it's level at the beginning of the period is negative, there is β-convergence which implies that the increase in the child survival probability in a given period of time is relatively faster in those countries where the child survival probability is low at the beginning of the period than in countries where it is relatively high. The existence of the β-convergence indicates the catching up process whereby countries with low child survival probability tend to catch up countries where the child survival probability is high. It is well-known that β-convergence is a necessary condition for σ-convergence across countries, although, it is not the sufficient (Baro and Sala-i-Martin, 1991; Quah, 1993; Young, Higgins and Levy; 2008).

The σ-convergence is commonly analysed in terms of measures of dispersion of the variable of interest across countries such as standard deviation, coefficient of variation and standard deviation of the logarithm of the variable of interest, etc. (Goli and Arokiasamy, 2008). A decrease in the inter-country measure of dispersion in the child survival probability signifies σ-convergence. Equation (1) suggests that inter-country convergence in p_u should be analysed in terms of the inter-country convergence in p_n, p_p and p_c. Measuring the inter-country dispersion in terms of the coefficient of variation, however, does not permit to analyse how the inter-country dispersion in p_c, p_p and p_n contributes to inter-country dispersion in p_u. Such a decomposition analysis is, however, important as the inter-country variation in p_u is essentially the result of the inter-country variation in p_c, p_p and p_n. To this end, we have measured the inter-country dispersion p_u in terms of the variance of the logarithm of p_u (vld_u) which is defined as

$$vld_u = \frac{\sum_{i=1}^{k}(\ln(p_{u_i}) - \mathrm{l}\ \ (p_{u_w}))^2}{k} \tag{2}$$

Here p_{u_w} is the weighted average of p_u across 190 countries and k is the number of countries. The advantage of using mld_u as the measure of inter-country dispersion is that it can be decomposed to reflect the contribution of the inter-country dispersion in p_c, p_p and p_n. It can be shown that

$$\begin{aligned} ln(p_{u_i}) - ln(p_{u_w}) &= ln(p_{c_i} * p_{p_i} * p_{n_i}) - ln(p_{c_w} * p_{p_w} * p_{n_w}) \\ &= [ln(p_{c_i}) - ln(p_{c_w})] + [ln(p_{p_i}) - ln(p_{p_w})] + \\ &\quad [ln(p_{n_i}) - ln(p_{n_w})] \end{aligned}$$

or

$$ln(p_{u_i}) - ln(p_{u_w}) = d_{u_i} = d_{c_i} + d_{p_i} + d_{n_i} \tag{3}$$

So that

$$\begin{aligned} vld_u = &\frac{\sum_{i=1}^{k} d_{c_i}^2 + \sum_{i=1}^{k} d_{c_i} * d_{p_i} + \sum_{i=1}^{k} d_{c_i} * d_{n_i}}{k} + \\ &\frac{\sum_{i=1}^{k} d_{p_i}^2 + \sum_{i=1}^{k} d_{p_i} * d_{n_i} + \sum_{i=1}^{k} d_{p_i} * d_{c_i}}{k} + \\ &\frac{\sum_{i=1}^{k} d_{n_i}^2 + \sum_{i=1}^{k} d_{n_i} * d_{p_i} + \sum_{i=1}^{k} d_{n_i} * d_{c_i}}{k} \end{aligned} \tag{4}$$

or

$$vld_u = \delta_c + \delta_p + \delta_n \tag{5}$$

Equation (5) decomposes the inter-country dispersion in p_u into three components – one attributed to the inter-country dispersion in p_c; second to the inter-country dispersion in p_p and third to the inter-country dispersion in p_n. Equation (5) permits analysing the relative importance of the inter-country dispersion in p_c, p_p and p_n to the inter-country dispersion in p_u.

On the other hand, the β-convergence has been analysed by regressing the change in child survival probability during a year on the level of child survival probability in the beginning of the year by using the regression equation (Rey and Montouri, 1999):

$$ln\left(\frac{p_{j_{i,t+k}}}{p_{j_{i,t}}}\right) = \alpha + \beta \ln(p_{j_{i,t}}) + \varepsilon_{i,t} \tag{6}$$

Where $j=u, c, p, n$. A negative value of the coefficient β confirms β-convergence across countries in the child survival probability.

Equation (1) also implies that the absolute change in the survival probability p_u can be decomposed as

$$\nabla p_u = p_u^2 - p_u^1 = p_c^2 * p_p^2 * p_n^2 - p_c^1 * p_p^1 * p_n^1 \quad (7)$$

Following Ang (2016), we can write

$$\nabla p_u = \frac{\nabla p_u}{r_{p_u}} * r_{p_u} \quad (8)$$

where

$$r_{p_u} = ln\left(\frac{p_u^2}{p_u^1}\right) \quad (9)$$

Now

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

or

$$r_{p_u} = r_{p_c} + r_{p_p} + r_{p_n} \quad (10)$$

Substituting from (10) into (8), we get

$$\nabla p_u = \nabla p_u * \left(\frac{r_{p_c}}{r_{p_u}}\right) + \nabla p_u * \left(\frac{r_{p_c}}{r_{p_u}}\right) + \nabla p_u * \left(\frac{r_{p_c}}{r_{p_u}}\right)$$

or

$$\nabla p_u = \partial p_c + \partial p_p + \partial p_n \quad (11)$$

Where

$\partial p_c = \nabla p_u * \left(\frac{r_{p_c}}{r_{p_u}}\right)$, etc.

It may be noticed that Equation (11) is true by definition so that the naive regression or correlation approaches, which ignore the sum constraint, are potentially problematic (Pooter and Werf, 1998; Wright and Westoby, 2001). Since, the contribution of the change in p_c, p_p and p_n to the change in p_u varies from country to country, an alternative approach (Preston, 1996) which is more appealing is to decompose inter-country variance in ∇p_u into the inter-country variance in ∂p_c, ∂p_p and ∂p_n as follows:

$$Var(\nabla p_u) = [Var(\partial p_c) + Cov(\partial p_c, \partial p_p) + Cov(\partial p_c, \partial p_n)] + [Var(\partial p_p) + Cov(\partial p_p, \partial p_c) + Cov(\partial p_p, \partial p_n)] + [Var(\partial p_n) + Cov(\partial p_n, \partial p_p) + Cov(\partial p_n, \partial p_c)]$$

or

$$Var(\nabla p_u) = V\partial p_c + V\partial p_p + V\partial p_n \quad (12)$$

where *Var* is the variance and *Cov* is the covariance. The first term on the right of equation (12) gives the contribution of the inter-country variance in the change in p_c to the inter-country variance in the change in p_c. Similarly, the second term gives the contribution of inter-country variance in the change in p_p while the third term gives the contribution of inter-country variance in the change in p_n. The relative importance of the inter-country variance in the change in p_c, p_p and p_n in explaining the inter-country variance in the change in p_u is given by

$$I_c = \frac{\nabla\partial p_c}{Var(\nabla p_u)} \qquad (13)$$

$$I_p = \frac{\nabla\partial p_p}{Var(\nabla p_u)} \qquad (14)$$

and

$$I_n = \frac{\nabla\partial p_n}{Var(\nabla p_u)} \qquad (15)$$

So that $I_c + I_p + I_n = 1$.

If P denotes the population size and BR denotes the birth rate so that $b=(BR/1000)$ and $L=P*b$ is the total number of live births, then the total number of survivors, S, in the first five years of life is given by

$$S = P*b*p_u = P*b*p_c*p_p*p_n \qquad (16)$$

The relative increase in the number of survivors, therefore, may be decomposed as

$$r_S = r_P + r_b + r_{p_c} + r_{p_p} + r_{p_n} \qquad (17)$$

and the change in the number of survivors, S, can be decomposed as

$$\nabla_S = S^2 - S^1 = \left(P^2 * b^2 * p_c^2 * p_p^2 * p_n^2\right) - \left(P^1 * b^1 * p_c^1 * p_p^1 * p_n^1\right) \qquad (18)$$

$$\nabla_S = \nabla_S * \frac{r_P}{r_S} + \nabla_S * \frac{r_b}{r_S} + \nabla_S * \frac{r_{pc}}{r_S} + \nabla_S * \frac{r_{pp}}{r_S} + \nabla_S * \frac{r_{pn}}{r_S}$$

$$\nabla_S = S_P + S_b + S_{p_c} + S_{p_p} + S_{p_n} \qquad (19)$$

Finally, if D denotes the total number of under-five deaths, then

$$\nabla_S = (L^2 - D^2) - (L^1 - D^1) = (L^2 - L^1) - (D^2 - D^1) = \nabla_L - \nabla_D$$

or

$$\nabla_D = \nabla_L - \nabla_S \qquad (20)$$

Now

$$\nabla_L = L^2 - L^1 = P^2 * b^2 - P^1 * b^1 = \frac{\nabla_L}{r_L} * r_P + \frac{\nabla_L}{r_L} * r_b \qquad (21)$$

Substituting from (8) and (10) in (9), we get

$$\nabla_D = [\nabla_L * \frac{r_P}{r_L} + \nabla_L * \frac{r_b}{r_L}] - [\nabla_S * \frac{r_P}{r_S} + \nabla_S * \frac{r_b}{r_S} + \nabla_S * \frac{r_{pc}}{r_S} + \nabla_S * \frac{r_{pp}}{r_S} + \nabla_S * \frac{r_{pn}}{r_S}]$$

$$\nabla_D = r_P\left(\frac{\nabla_L}{r_L} - \frac{\nabla_S}{r_S}\right) + r_b\left(\frac{\nabla_L}{r_L} - \frac{\nabla_S}{r_S}\right) + \left(-r_{p_c} * \frac{\nabla_S}{r_S}\right) + \left(-r_{p_p} * \frac{\nabla_S}{r_S}\right) + \left(-r_{p_n} * \frac{\nabla_S}{r_S}\right)$$

$$\nabla_D = D_P + D_b + D_{p_c} + D_{p_p} + D_{p_n} \qquad (22)$$

Equation (22) is a five-factor decomposition model of the change in the number of under-five deaths. The change in the number of under-five deaths is contingent upon not only the change in child survival probabilities but also to the change in fertility and population size.

Child Survival Progress, 1990-2015

The weighted average q_u for 190 countries decreased from around 0.092 in 1990 to around 0.042 in 2015 or by less than 55 per cent. If the goal set in the Millennium Development Agenda would have been achieved, then the weighted average q_u would have decreased to 0.308 in 2015. There are only 58 countries where q_u decreased by at least by two-third between 1990-2015 (Table 1). Moreover, q_u did not decrease in all countries but increased in three countries – Dominica, Lesotho and Swaziland. The decrease in q_u was associated with the decrease in q_c from 0.030 to 0.011; the decrease in q_p from 0.028 to 0.012; and the decrease in q_n from 0.037 to 0.019. However, neither q_c, nor q_p and q_c decreased in all countries; q_c, increased, in three countries - Antigua & Barbuda, Lesotho and Swaziland; q_p increased in five countries - Dominica, Grenada, Lesotho, Seychelles and Swaziland; while q_n increased in four countries - Botswana, Dominica, Monaco and Swaziland - during the period under reference.

Alternatively, p_u, increased from 0.908 to 0.958; p_c increased from 0.970 to 0.989; p_p from 0.972 to 0.988; and p_n from 0.963 to 0.981 during 1990-2015 in the 190 countries. The inter-country distribution of the relative increase in p_u, p_c, p_p and p_n is summarised in table 2 and the cumulative distribution of the relative increase in the survival probabilities is depicted in figure 1. The inter-country distribution of the relative increase in all the four survival probabilities is positively skewed which implies that the proportion of countries recording above average relative increase in all the four survival probabilities was lower than the proportion of countries recording below average relative increase in these survival probabilities so that the median of the relative increase across countries was substantially lower than the average relative increase in all the four survival probabilities. Moreover, the kurtosis of the inter-country distribution of all the four survival probabilities is positive and is the highest for the inter-country distribution of the relative change in p_c but the lowest for the inter-country distribution of the relative change in p_n. Kurtosis reflects the tail extremity or the tailedness of the inter-country distribution of the relative increase in the survival probability – the higher the kurtosis the heavier the tails of the inter-country distribution and vice versa (Westfall, 2014).

The improvement in p_u is determined by the improvement in p_c, p_p and p_n. This means that in every country, the relative increase in p_u is contingent upon the relative increase in p_c, p_p and p_n. In order to characterise the relative increase in p_u in the context of the relative increase in p_c, p_p and p_n across the countries, we have followed the classification modelling approach (Tan, Steinbach and Kumar, 2006; Han, Kamber and Pei, 2012) and applied the classification tree (CRT) method to classify countries in terms of the relative increase in p_u during 1990-2015 in the context of the relative increase in p_c, p_p, and p_n. The classification and regression tree method is a non-parametric recursive partitioning method which divides countries into mutually exclusive groups in such a way that within-group homogeneity in the relative increase in p_u is the maximum (Brieman et al, 1984). The method sorts countries on the basis of the relative increase in p_c, p_p and p_n which causes the most effective split. The process is repeated until either the perfect within-group similarity in the relative increase in p_u is achieved or a pre-decided stopping criterion is met (Lemon et al, 2003). A group in which all countries have the same value of the relative increase in p_u is termed as "pure." If a group is not "pure", then the within-group impurity can be measured through the impurity measure. In the present exercise, we have used the Gini coefficient of impurity to measure the within-group impurity in the relative increase in p_u - the higher the Gini coefficient of impurity, the larger is the variation in the relative increase in p_u across countries within the same group.

Results of the classification modelling exercise are presented in table 3 and the classification tree is depicted in figure 2. The classification tree has seven terminal nodes which implies that the 190 countries can be divided into seven mutually exclusive groups in terms of the relative increase in p_u and the child survival perspective – in terms of the relative increase in p_c, p_p and p_n – is essentially different in the seven groups. The relative increase in p_u, on average, was the slowest in group 1 (node 7) which comprises of 69 (36.3 per cent) countries and accounted for almost 17 per cent of the world population in 2015. Countries of this group are characterised by very slow increase in p_c, and p_p. At the other extreme, the relative increase in p_u, on average, was the most rapid in group 7 (node 6) which comprises of 7 countries and accounted for less than 1.5 per cent population of the world in 2015. Countries of this group are characterised by the most rapid relative increase in p_c. The classification modelling exercise suggests that the relative increase in p_u across the countries was directly related to the relative increase in both p_c and p_p – the faster the relative increase in p_c or p_p the faster the relative increase in p_u. The relative increase in p_n, on the other hand, was found to be important in deciding the relative increase in p_u in only a small proportion of countries. Table 3 indicates that in close to three-fourth of the countries, the relative increase in p_u during 1990-2015 was less than 5 per cent, on average. There were only about 20 per cent countries, where the relative increase in p_u during 1990-2015 was, on average, at least 10 per cent (Table 4).

The Millennium Development Agenda of the United Nations was launched in the year 2000 but the reference year for monitoring the progress of the targets set under the Agenda was set to be the year 1990. It may be argued that the pace of decrease in the under-five mortality might have accelerated after the launch of the Millennium Development Agenda in 2000. To test this hypothesis, we have fitted the piecewise linear regression model (Ryan and Porth, 2007) to the time series of q_u for each of the 190 countries assuming that the pace of decrease in q_u during 1990-2000 was essentially different from the pace of decrease during 2000-2010 and the pace of decrease during 2010-2015 was different from that during 2000-2010. The analysis revealed that, compared to 1990-2000, the decrease in q_u accelerated during 2000-2015 in only 109 or in 57 per cent countries. On the other hand, relative to the pace of decrease during 2000-2010, the pace of decrease in q_u accelerated during 2010-2015 in only 43 per cent of the countries. In the remaining countries, the pace of decrease either slowed down or remained unchanged.

The increase in p_u in all but three of the 190 countries during 1990-2015 had also been associated with the decrease in the level of fertility and the increase in the size of the population both of which have an impact on the number of survivors in the first five years of life and on the number of under-five deaths as well as on the deaths in neonatal and post-neonatal periods and deaths during 1-4 years of life in addition to the improvement in the survival probability during neonatal and post neonatal periods and during 1-4 years of life. The population of the 190 countries increased from 5.297 billion to 7.342 billion between 1990-2015 while the birth rate decreased from 25.8 to 19.0 live births per 1000 population during this period. As the result, the number of survivors in the first five years of life increased by around 9.64 million from 12.39 million in 1990 to 13.35 million in 2015. At the same time, the number of under-five deaths, in these countries, decreased by around 6.77 million from about 12.60 million in 1990 to around 5.83 million in 2015. In 1990, around 40 per cent of the under-five deaths was neonatal deaths while post neonatal deaths and deaths in 1-4 years of life, each, accounted for about 30 per cent of the total under-five deaths. In 2015, neonatal deaths as proportion to the under-five deaths increased to around 46 per cent while the proportion of deaths in 1-4 years of life decreased to about 25 per cent. There was little change in the proportion of post-neonatal deaths.

Convergence Analysis

Results of the σ-convergence analysis are presented in table 5 and figure 3. The inter-country dispersion in p_u decreased throughout 1990-2015 except in 1994 and 2010. The increase in the inter-country dispersion in p_u in both 1994 and 2010 was primarily due to the increase in inter-country dispersion in p_c. In 1991, the increase in inter-country dispersion in p_c might be attributed to the genocide in Rwanda as the result of which, the probability of survival in 1-4 years of life in the country decreased from 0.911 in 1993 to 0.811 in 1994 leading to a decrease in the probability of survival in the first five years of life from 0.816 in 1993 to 0.716 in 1994. In 2010, the increase in inter-country dispersion in p_c might be attributed to the devastating earth- quake in Haiti which resulted in a decrease in the probability of survival in 1-4 years of life from 0.977 in 2009 to 0.862 in 2010 leading to a decrease in the probability of survival in the first five years of life from 0.919 in 2009 to 0.792 in 2010. The decomposition of inter-country dispersion in p_u suggests that σ-convergence in p_u was attributed largely to σ-convergence in p_c. Nearly 47 per cent of the decrease in the inter-country dispersion in p_u was attributed to the decrease in the inter-country dispersion in p_c; around 31 per cent to the decrease in the inter-country dispersion in p_p whereas only around 22 per cent to the decrease in the inter-country dispersion in p_n. This means that the reduction in the inter-country disparity in p_u during 1990-2015 was largely due to the reduction in the inter-country disparity in p_c. The role of the reduction in the inter-country disparity in p_n in reducing the inter-country disparity in p_u had, at best been marginal.

Results of the β-convergence analysis are presented in table 6 and the trend in the regression coefficient is depicted in figure 4. The β-convergence analysis was carried out after excluding two countries - Rwanda and Haiti. The survival probability in the first five years of life decreased very sharply in Rwanda in 1994 because of the genocide in 1994. On the other hand, the probability of survival in the first five years of life decreased very sharply in Haiti because of the devastating earth-quake in Haiti in 2010. Since sudden, very rapid decrease in the child survival probability in the two countries was an outlier, the two countries were excluded from the analysis and the regression analysis was confined to 188 countries only. The results of the regression analysis confirm that the pace of improvement in p_u during 1990-2015 was relatively faster in those countries where p_u was relatively low in 1990 as compared to countries where p_u in 1990 was relatively high. In other words, countries having low level of p_u in 1990, were able to catch-up the countries having high p_u in 1990 during 1990-2015, although the pace of catching-up process was not very fast. Moreover, the speed of convergence in p_u as well as in p_c, p_p and p_n varied in different years of the period 1990-2015. The speed of convergence in p_u accelerated during 1997-2004 and nearly remained unchanged during 2004-2010. However, the speed of convergence slowed down considerably after 2010 suggesting that the pace of the increase in p_u slowed down in many countries where the level of p_u in 2010 was still high or very high. A similar trend can also be observed in the case of the speed of convergence in p_c and p_p but the speed of convergence in p_n across countries accelerated during a short period of 1997 through 2000 only and, since then, there was virtually little change in the speed of convergence. The table also suggests that the speed of convergence across countries was relatively the fastest in p_c but relatively the slowest in p_n. On the other hand, the speed of convergence in p_p was very similar to that in p_u. This implies that catching up process in p_u was driven largely by the catching up process in p_c. Countries with low to very low p_u were able to achieve an accelerated improvement in p_u during 1990-2015 mainly because of the accelerated improvement in p_c. The reduction in the inter-country disparity in p_p and p_n appears to have played only a marginal role in reducing the inter-country disparity in p_u.

Decomposition of the Change in the Survival Probability p_u and Number of Survivors

In absolute terms, p_u increased by around 0.050 points between 1990 and 2015 in the 190 countries. Nearly 36 per cent of this increase was attributed to the increase in p_c; around 30 per cent to the increase in p_p; and almost 34 per cent to the increase in p_n. The increase in p_u, however, was not uniform during different years of the period under reference (Table 7). The increase in p_u accelerated during the 10 years after the launch of Millennium Development Agenda (2000-2010) but the rate of increase in p_u slowed down considerably after 2010 indicating that the impetus for preventing child deaths generated after the launch of the Millennium Development Agenda was lost in many countries after 2010. The average annual increase in p_u was 0.0016 absolute points per year, on average, during 1990-2000 which accelerated to more than 0.0025 absolute points per year, on average, during 2000-2010. However, after 2010, the p_u increased, on average, by only about 0.0018 absolute points per year, on average. It may also be seen from figure 5 that the acceleration in the increase in p_u primarily because of the acceleration in the increase in p_c. After 2010, the momentum of the increase in p_c slowed down considerably leading to the slowdown in the pace of increase in p_u.

The absolute increase in p_u and the associated absolute increase in p_c, p_p and p_n had varied widely across the 190 countries. The decomposition of the inter-country variance in the absolute increase in $p_{\underline{u}}$ suggests that more than half of the inter-country variance in the absolute increase in p_u during 1990-2015 was attributed to the inter-country variance in the absolute increase in p_c whereas the inter-country variance in the absolute increase in p_n accounted for only about 17 per cent of the inter-country variance in the absolute increase in p_u (Table 7). The remaining 33 per cent of the inter-country variance in the absolute increase in p_u was explained by the inter-country variance in the absolute increase in p_p. In other words, the inter-country variation in the absolute increase in p_u during 1990-2015 was largely determined by the inter-country variation in the absolute increase in p_c. The inter-country variation in the absolute increase in p_p contributed only marginally to the inter-country variation in the absolute increase in p_u whereas the contribution of the inter-country variation in the absolute increase in p_n played only a limited role in deciding the inter-country variation in the absolute increase in p_u.

The increase in p_c, p_p and p_n along with the increase in the size of the population and decrease in the birth rate resulted in an increase in the number of survivors in the first five years of life by about 9.64 million – from around 12.39 million in 1990 to 13.35 million in 2015. The increase in the population actually resulted in an increase of 42 million in the number of survivors in the first five years of life but this increase was almost compensated by a decrease of around 39.3 million survivors as the result of the decrease in the birth rate. On the other hand, in increase in p_c resulted in an increase of 2.5 million; the increase in p_p resulted in an increase of 2.10 million and the increase in p_n resulted in an increase of 2.36 million in the number of survivors during the first five years of life. The increase in the number of survivors, however, was confined to only 112 countries. In 78 countries, the number of survivors in the first five years of life decreased despite the improvement in the survival probability in the first five years of life. In these countries, the decrease in the number of survivors as the result of the decrease in birth rate was larger than the increase in the number of survivors as the result of the increase in population size and the improvement in the child survival probability. In China, the number of survivors decreased by almost 7.7 million between 1990 and 2015 despite improvement in child survival probabilities because a very rapid decrease in the birth rate as the result of some very stringent fertility reduction measures induced a reduction of more than 12 million survivors.

Decomposition of the Decrease in the Number of Under-five Deaths

The number of under-five deaths in the 190 countries decreased by around 6.77 million or by about 54 per cent between 1990 and 2015 (Table 8). Deaths in 1-4 years decreased by around 61 per cent; deaths in the postnatal period decreased by around 55 per cent; and deaths in the neonatal period decreased by only about 47 per cent. The decomposition of the decrease in the number of under-five deaths suggests that around 37 per cent of the decrease in these deaths was attributed to the increase in p_c; around 31 per cent to the increase in p_p; and around 35 per cent to the increase in p_n. In addition, around 42 per cent of the decrease in the number of under-five deaths was attributed to the decrease in fertility. This means that improvement in the child survival probability and transition in fertility, actually, saved around 9.79 million under-five deaths between 1990 and 2015 in 190 countries. However, population of these countries increased from around 5.297 billion in 1990 to around 7.342 billion in 2015 which resulted in an increase of 3.03 million under-five deaths. As the result, the net decrease in the number of under-five deaths between 1990 and 2015 was reduced to 6.77 million. The child survival progress, during 1990-2015, actually, resulted in preventing 6.96 million under-five deaths – 2.36 million neonatal deaths, 2.10 million post neonatal deaths and 2.56 million deaths of children aged 1-4 years.

The child survival progress in the seven groups of countries identified through the classification modelling exercise had essentially been different. Countries of group 1 (node 7), accounting for almost 20 per cent of the population of 190 countries in 2015, accounted for only 2 per cent of the total decrease in the number of under-five deaths whereas countries of group 5 (node 11), also accounting for around 20 per cent population of 190 countries, accounted for almost 36 per cent of the total decrease in the number of under-five deaths. Countries of group 3 (node 9), accounting for almost 30 per cent of the population, also accounted for more than 26 per cent of the decrease in the total number of under-five deaths. This means that around 62 per cent of the decrease in the number of under-five deaths in 190 countries between 1990 and 2015 was confined to only 39 countries which accounted for almost half of the population of 190 countries in 2015.

The seven groups of countries differed significantly in terms of the child survival scenario in 1990 which largely determined the child survival progress during 1990-2015. The child survival probabilities were the highest in countries of group 1 where the improvement in child survival probabilities during 1990-2015 was relatively the slowest. On the other hand, child survival probabilities were relatively the lowest in countries of group 7 currently as well as in the past but the increase in p_u was relatively the fastest in countries of this group primarily because of the rapid improvement in the survival probability in 1-4 years of life.

The decrease in the number of under-five deaths was the most rapid in Maldives - the only country where the number of under-five deaths decreased by more than 90 per cent during 1990-2015. In addition, there are only 20 countries where the number of under-five deaths decreased by 80-90 per cent during 1990-2015. These include China, the most populous country of the world where the number of under-five deaths decreased by almost 87 per cent between 1990 and 2015. By comparison, the number of under-five deaths in India, the second most populous country of the world, decreased by only around 66 per cent during this period. More than 40 per cent of the decrease in the under-five deaths in China was attributed to the decrease in the neonatal mortality and around 35 per cent to the decrease in fertility. The decrease in the postnatal mortality and mortality in 1-4 years of age accounted for around 35 per cent of the decrease in the under-five deaths whereas population growth accounted for only around 10 per cent of the increase in under-five deaths. In India, more than 93 per cent of the decrease in the under-five deaths was attributed to the decrease in neonatal and postnatal mortality and mortality in 1-4 years of age while the decrease in fertility accounted for almost 48 per cent of the decrease in the under of under-five deaths. However, population growth during 1990-2015 accounted for an increase of almost 41 per cent in the under-five deaths during 1990-2015.

On the other hand, the number of under-five deaths increased, instead decreased, during 1990-2015 in 14 countries. In 11 of these countries, neonatal and postnatal mortality and mortality in 1-4 years of age decreased along with the decrease in fertility but the decrease in the number of under-five deaths as the result of the transition in fertility and the increase in child survival probabilities was not large enough to compensate for the increase in the under-five deaths as the result of the increase in the size of the population so that number of under-five deaths in these countries increased, instead decreased. In the remaining three countries, either neonatal mortality or postnatal mortality or mortality in 1-4 years of age increased which contributed to the increase, not decrease, in the number of under-five deaths.

Finally, if the 190 countries, as a group, would have been able to reduce the probability of death during the first five years of life (q_u) by two-third between 1990 and 2015 as targeted in the Millennium Development Agenda of the United Nations, then the number of under-five deaths would have decreased by around 8.31 million instead of 6.77 million under the assumption that the pace of fertility transition and the rate of population growth during this period would have remained unchanged in all countries. This means that more than 1.54 million deaths of children below five years of age could not be saved between 1990-2015 primarily because majority of the countries included in the present analysis could not achieve the target of reducing the probability of death in the first five years of life (q_u) by at least two-third as stipulated in the United Nations Millennium Development Agenda.

Conclusions

The foregoing analysis depicts a dis-quietening picture of child survival progress in 190 countries during 1990-2015 despite the emphasis laid down on preventing premature child deaths in the United Nations Millennium Development Agenda. It appears that most of the countries could not be able to mobilise resources necessary for the realisation of the commitment made by them by endorsing the Millennium Development Agenda. As a result, the life of at least 1.5 million children below five years of age could not be saved during 1990-2015. It appears that, despite endorsing the Millennium Development Agenda, majority of the countries lacked the political commitment necessary to mobilise additional resources for preventing premature death of children thereby hastening the global progress towards child survival. The target of reducing under-five mortality at least by two-third set under the Millennium Development Agenda was relative in nature which means that every country, irrespective of the level of under-five mortality, should have mobilised additional resources for further reduction in under-five mortality by preventing premature child deaths. However, close to 70 per cent countries included in the analysis failed to do so. The failure to achieve two-third reduction in under-five mortality during 1990-2015 was not confined either the least developed or the developing countries but the developed countries also. It may be argued that child mortality levels were already very low in these countries as early as in 1990. However, it is obvious from the present analysis that there is still substantial scope of child survival progress in at least two-third of these countries.

The causes of under-five deaths, according can be divided into the 'hard' rock or endogenous causes and the 'soft' rock exogenous causes of under-five deaths (Bourgeois-Pichat, 1978). Eroding the 'soft' rock of child deaths is relatively easier as most of the child deaths due to exogenous causes can be prevented the low-cost appropriate health technology such as immunization against vaccine preventable diseases and improvements in the standards of living including improvements in the nutritional status of women and children. Eroding the 'hard' rock of under-five mortality is, however, difficult as it requires advanced health technology and heavy investment in the health care delivery system. It is well-known that when under-five mortality is high, majority of under-five deaths are due to exogenous causes but as under-five mortality decreases, the proportion of under-five deaths due to endogenous causes increases so that an increasing proportion of under-five deaths gets concentrated in the neonatal period. This implies that with the decrease in the under-five mortality, investment in children should be increase to maintain the child survival progress. The present analysis, however, suggests that the child survival progress during 1990-2015 was arrived at largely by eroding the 'soft' rock of under-five mortality.

The analysis also highlights the importance of reduction in fertility and controlling population growth in the decrease in the number of under-five deaths. In at least 12 countries, the improvement in the survival probabilities during childhood were the most rapid during 1990-2015 but most of the advantage of this rapid improvement in child survival probabilities in terms of the decrease in the number of under-five deaths was lost because of the increase in the number of under-five deaths because of the rapid population growth and the persistence of high fertility. Minimising the effect of population growth on the number of under-five deaths requires acceleration in fertility transition which implies that family planning should be an integral part of any strategy towards reducing premature under-five deaths.

Efforts to promote child survival have primarily been built around the integrated management of childhood illness (IMCI) strategy launched by WHO and UNICEF in 1995 and later expanded to include neonatal care in 2003 and renamed as integrated management of neonatal and childhood illness (IMNCI). A review of the strategy in 2016, however, had concluded that, over a period of 20 years, interest and funding for IMNCI have waned, implementation 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 immunization continued to be the focus of attention. There is a need of an integrated, well-funded child survival programme that aligns, maternal, newborn, and child health under a common national vision with country specific targets to accelerate the progress towards child survival.

Finally, there appears a need to revisit the targets of reducing child mortality set under the United Nations 2030 Sustainable Development Agenda. There are 112 countries which had already achieved under-five mortality rate of less than or equal to 25 under-five deaths per 1000 live births as early as in 2015 but there were 0.61 million under-five deaths in these countries in 2015. Similarly, the neonatal mortality rate was also less than or equal to 12 neonatal deaths per 1000 live births in 112 countries in 2015 and there were more than 0.29 million neonatal deaths in these countries in 2015. It is obvious many of these deaths can be prevented and the probability of survival during the neonatal period and during the first five years of life can be improved further by increasing the investment on children in these countries. However, the 2030 Sustainable Development Agenda provides little impetus for increasing the investment on children in these countries.

References

Ang BW (2016) A simple guide to LMDI decomposition analysis. Singapore, National University of Singapore. Department of Industrial and Systems Engineering.

Barro RJ, Sala-I-Martin X (1991) Convergence across the states and regions. *Brookings Papers on Economic Activities* 22: 107–158.

Bhutta ZA, Chopra M, Axelson H, Berman P, Boerma T, Bryce J, Bustreo F, Cavagnero E, Cometto G, Daelmans B, de Francisco A, Fogstad H, Gupta N, Laski L, Lawn J, Maliqi B, Mason E, Pitt C, Requejo J, Starrs A, Victora CG, Wardlaw T (2010) Countdown to 2015 decade report (2000–10): taking stock of maternal, newborn, and child survival. *Lancet* 375: 2032–44.

Bourgeois-Pichat J (1978) Future outlook of mortality decline in the worlds. *Population Bulletin of the United Nations* 11: 12-41.

Brieman L, Friedman JH, Olshen RA, Stone CJ (1984) *Classification and Regression Trees*. New York, CRC Press.

Goli S, Arokiasamy P (2014) Maternal and child mortality indicators across 187 countries of the world: Converging or diverging. *Global Public Health: An International Journal for Research, Policy and Practice*. DOI: 10.1080/17441692.2014.890237

Han J, Kamber M, Pei J (2012) *Data Mining. Concepts and Techniques*. Amsterdam, Elsevier.

Lemon SC, Roy J, Melissa A, Clark PD, Friedman WR (2003) Classification and Regression Tree Analysis in public health: methodological review and comparison with logistic regression. *Annals of Behavioral Medicine* 26: 172-181.

Lozano R, Wang H, Foreman KJ, Rajaratnam JK, Naghavi M, Marcus JR, Dwyer-Lindgren L, Lofgren KT, Phillips D, Atkinson C, Lopez AD, Murray CJL (2011) Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis. *Lancet* 378: 1139–65.

Poorter A, van der Werf A (1998) Is inherent variation in RGR determined by LAR at low irradience and by NAR at high irradience? A review of herbaceous species. In H Lambers, H Poorter and MML Van Vuuren (Eds) *Inherent Variation in Plant Growth*: *Physiological Mechanisms and Ecological Consequences*. Leiden: Backhuys

Quah D (1993) Gallon's fallacy and tests of the convergence hypothesis. *Scandinavian Journal of Economics* 95: 427–443.

Rajaratnam JK, Marcus JR, Flaxman AD, Wang H, Levin-Rector A, Dwyer L, Costa M, Lopez AD, Murray CJL (2010) Neonatal, postneonatal, childhood, and under-5 mortality for 187 countries, 1970–2010: a systematic analysis of progress towards Millennium Development Goal 4. *Lancet* 375: 1988–2008.

Rey SJ, Montouri BD (1999) US regional income convergence: a spatial econometric perspective. *Regional Studies* 33: 143–156.

Ryan SE, Porth LS (2007) A tutorial on the piecewise regression approach applied to bedload transport data. Fort Collins CO, US Department of Agriculture, Forest Services, Rockey Mountain Research Station. General Technical Report RMRC-GTR-189.

Tan P-N, Steinbach M, Kumar V (2006) *Introduction to Data Mining*. New Delhi, Pearson Education.

United Nations Children's Fund (2015) *Levels and Trends in Child Mortality. Report 2015. Estimates Developed by United Nations Inter-Agency Group on Child Mortality Estimation.* New York, United Nations Children's Fund.

United Nations Children's Fund (2017) *Levels and Trends in Child Mortality. Report 2017. Estimates Developed by United Nations Inter-Agency Group on Child Mortality Estimation.* New York, United Nations Children's Fund.
United Nations Children's Fund (2018) *Explanatory Notes Child Mortality Trend Series 2017*. New York, United Nations Children's Fund.
United Nations (2000) *United Nations Millennium Declaration*. New York, United Nations. (A/Res/55/2).
United Nations (2015) *Transforming our World: The 2030 Agenda for Sustainable Development*. New York, United Nations.
United Nations (2016) *Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators.* New York, United Nations (E/CN.3/2016/2/Rev.1).
United Nations (2017) *World Population Prospects: The 2017 Revision, Volume I: Comprehensive Tables*. ST/ESA/SER.A/379. New York, United Nations, Department of Economic and Social Affairs, Population Division.
You D, Jones G, Hill K, Wardlaw T, Chopra M (2010) Levels and trends in child mortality, 1990–2009. *Lancet* 376: 931–33.
You D, Hug L, Ejdemyr S, Idele P, Hogan D, Mathers C, Gerland P, New JR, Alkema L, for the United Nations Inter-Agency Group for Child Mortality Estimation (UN IGME) (2015) Global, regional, and national levels and trends in under-5 mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Inter-Agency Group for Child Mortality Estimation. *Lancet* 386: 2275–86.
Young AT, Higgins MJ, Levy D (2008) Sigma convergence versus beta convergence: evidence from US county level data. *Journal of Money, Credit and Banking* 40(5): 1083-1093.
Westfall PH (2014) Kurtosis as peakedness 1905-2014, *R.I.P. American Statistician* 68(3): 191-195.
World Health Organization (2016) *Towards a Grand Convergence for Child Survival and Health*. Geneva, World Health Organization.
Wright IJ, Westoby M (2001) Understanding seedling growth relationships through specific leaf area and leaf nitrogen concentration: generalisations across growth forms and growth irradiance. *Oecologia* 127(1), 21–29.

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Table 1
Decrease in child mortality during 1990-2015 relative to 1990

Percentage decrease	Child mortality indicator							
	q_u		q_u		q_u		q_u	
	Number	%	Number	%	Number	%	Number	%
≥66	58	30.5	87	45.8	84	44.2	36	18.9
50-66	80	42.1	67	35.3	59	31.1	59	31.1
33-50	33	17.4	22	11.6	26	13.7	52	27.4
0-33	16	8.4	10	5.3	16	8.4	34	17.9
< 0	3	1.6	3	1.6	5	2.6	4	2.1
N	190	100.0	190	100.0	190	100.0	190	100.0

Source: Author’s calculations based on UN IGME estimates

Table 2

Summary measures of the distribution of the proportionate increase in child survival probability in 190 countries, 1990-2015

Measure	p_u	p_c	p_p	p_n
Minimum	-1.617	-0.556	-0.326	-1.345
Q1	0.896	0.149	0.261	0.440
Median	2.516	0.538	0.841	0.923
Q3	6.878	2.319	2.323	1.725
Maximum	34.853	23.020	9.802	4.702
Inter-quartile range	5.982	2.270	2.062	1.285
Unweighted mean	4.861	1.859	1.624	1.220
Weighted mean	5.560	1.960	1.649	1.852
Standard deviation	5.753	2.930	1.865	1.027
Skewness	1.983	3.091	1.743	1.144
Kurtosis	4.790	14.781	3.290	1.311
N	190	190	190	190

Source: Author's calculations

Table 3
Classification of countries in terms of proportionate increase in p_u during 1990-2015

Group	Tree node	Group characteristics		Mean ∇p_u		SD	Number of countries
		∇p_c	∇p_p	Weighted	Unweighted		
1	7	≤0.009	≤0.004	0.006	0.007	0.005	69
2	8	≤0.009	>0.004	0.021	0.023	0.008	41
3	9	>0.009, ≤0.033	≤0.024	0.042	0.047	0.011	30
4	10	>0.009, ≤0.033	>0.024	0.065	0.075	0.010	13
5	11	>0.033, ≤0.084	≤0.050	0.094	0.112	0.016	22
6	12	>0.033, ≤0.084	>0.050	0.164	0.160	0.017	8
7	6	>0.084		0.237	0.237	0.054	7

Source: Author's calculations

Table 4
Classification of countries by relative increase in p_u during 1990-2015

Groups	Countries
Group 1	Andorra, Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, San Marino, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, United States, Bahamas, Bahrain, Barbados, Brunei Darussalam, Costa Rica, Cuba, Cyprus, Dominica, Fiji, Grenada, Israel, Jamaica, Kuwait, Malaysia, Mauritius, Panama, Qatar, Saint Lucia, Samoa, Seychelles, Singapore, South Africa, Sri Lanka, Swaziland, Tonga, Trinidad and Tobago, United Arab Emirates, Lesotho, Vanuatu
Group 2	Albania, Bosnia and Herzegovina, Macedonia, Moldova, Romania, Russian Federation, Serbia, Algeria, Antigua and Barbuda, Argentina, Armenia, Belize, Botswana, Chile, Colombia, Dominican Republic, Georgia, Guyana, Iraq, Jordan, Kazakhstan, Korea DPR, Korea Rep, Lebanon, Libya, Marshall Islands, Mexico, Micronesia (Federated States of), Oman, Palau, , Paraguay, Saint Kitts and Nevis, Saudi Arabia, Solomon Islands, State of Palestine. Suriname, Syrian Arab Republic, Thailand, Uruguay, Venezuela (Bolivarian Republic of), Zimbabwe
Group 3	Brazil, Cabo Verde, Cameroon, China, Congo, Ecuador, El Salvador, Gabon, Guatemala, Honduras, Iran (Islamic Republic of), Kenya, Kyrgyzstan, Morocco, Namibia, Nicaragua, Papua New Guinea, Philippines, Tunisia, Turkey, Turkmenistan, Uzbekistan, Viet Nam, Central African Republic, Comoros, Djibouti, Kiribati, Mauritania, Myanmar, Somalia
Group 4	Azerbaijan, Côte d'Ivoire, Egypt, Ghana, Indonesia, Maldives, Pakistan, Peru, Tajikistan, Cambodia, Sao Tome and Principe, Sudan, Yemen
Group 5	Bolivia (Plurinational State of), India, Mongolia, Nigeria, Afghanistan, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Chad, Congo DR, Equatorial Guinea, Eritrea, Gambia, Haiti, Lao People's Democratic Republic, Madagascar, Nepal, Rwanda, Senegal, Togo
Group 6	Angola, Ethiopia, Guinea, Guinea-Bissau, Tanzania, Timor-Leste, Uganda, Zambia
Group 7	Liberia, Malawi, Mali, Mozambique, Niger. Sierra Leone, South Sudan

Table 5
Proportionate distribution of child deaths across seven groups of countries

Group	Under-five deaths		Deaths in 1-4 years of life		Post neonatal deaths		Neonatal deaths	
	1990	2015	1990	2015	1990	2015	1990	2015
1 (Node 7)	1.86	2.29	1.13	1.61	2.15	2.99	2.20	2.21
2 (Node 8)	4.30	4.20	2.69	2.84	4.80	4.20	5.15	4.95
3 (Node 9)	21.46	13.48	17.16	11.66	21.06	15.03	25.00	13.49
4 (Node 10)	12.79	15.97	11.25	13.12	14.38	14.48	12.79	18.45
5 (Node 11)	46.24	47.60	49.83	49.94	42.66	46.37	46.18	47.11
6 (Node 12)	8.37	10.15	10.78	12.27	9.48	10.14	5.73	8.99
7 (Node 6)	4.97	6.31	7.37	8.56	5.46	6.78	2.95	4.79
All	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Number of deaths (million)	12.60	5.83	3.81	1.46	3.73	1.69	5.06	2.68

Table 6

Variance of the logarithm of p_u, p_c, p_p and p_n across 190 countries

Year	Variance of the logarithm of				Contribution of the variance of the logarithm of p_c, p_p and p_n to the variance of the logarithm of p_u		
	p_u	p_c	p_p	p_n	p_c	p_p	p_n
1990	0.007	0.003	0.002	0.002	44.1	31.4	24.5
1991	0.006	0.003	0.002	0.002	43.9	31.6	24.5
1992	0.006	0.003	0.002	0.002	43.7	31.7	24.6
1993	0.006	0.003	0.002	0.001	43.5	31.8	24.7
1994	0.006	0.003	0.002	0.001	44.7	31.3	24.0
1995	0.006	0.003	0.002	0.001	43.7	31.6	24.7
1996	0.005	0.002	0.002	0.001	42.5	32.0	25.4
1997	0.005	0.002	0.002	0.001	42.5	32.0	25.5
1998	0.005	0.002	0.002	0.001	42.5	32.0	25.5
1999	0.005	0.002	0.002	0.001	41.7	32.2	26.1
2000	0.004	0.002	0.001	0.001	41.3	32.3	26.4
2001	0.004	0.002	0.001	0.001	40.9	32.3	26.8
2002	0.004	0.002	0.001	0.001	40.4	32.3	27.3
2003	0.003	0.001	0.001	0.001	39.9	32.3	27.9
2004	0.003	0.001	0.001	0.001	39.3	32.2	28.4
2005	0.003	0.001	0.001	0.001	38.8	32.3	28.9
2006	0.003	0.001	0.001	0.001	38.3	32.2	29.5
2007	0.002	0.001	0.001	0.001	37.8	32.1	30.1
2008	0.002	0.001	0.001	0.001	37.3	32.2	30.6
2009	0.002	0.001	0.001	0.001	36.5	32.1	31.3
2010	0.002	0.001	0.001	0.001	39.2	31.2	29.6
2011	0.002	0.001	0.001	0.001	35.3	32.0	32.7
2012	0.002	0.001	0.000	0.001	34.6	32.1	33.3
2013	0.001	0.000	0.000	0.000	34.1	32.1	33.8
2014	0.001	0.000	0.000	0.000	33.6	32.0	34.4
2015	0.001	0.000	0.000	0.000	33.1	32.0	34.9

Source: Author's calculations

Table 7

Coefficient of regression of the change in p_c, p_c, p_p and p_n during 1990-2015 on initial level of p_u, p_c, p_p, and p_n, across 188 countries

Period	Beta coefficient				Speed of convergence			
	p(u)	p(c)	p(p)	p(n)	p(u)	p(c)	p(p)	p(n)
1990-91	-0.016	-0.020	-0.012	-0.014	0.016	0.021	0.012	0.015
1991-92	-0.017	-0.022	-0.012	-0.014	0.017	0.023	0.012	0.014
1992-93	-0.018	-0.024	-0.015	-0.011	0.018	0.024	0.015	0.011
1993-94	-0.018	-0.025	-0.016	-0.012	0.019	0.025	0.016	0.012
1994-95	-0.020	-0.027	-0.019	-0.012	0.020	0.028	0.019	0.012
1995-96	-0.021	-0.028	-0.019	-0.013	0.021	0.029	0.020	0.013
1996-97	-0.022	-0.029	-0.023	-0.013	0.023	0.029	0.023	0.013
1997-98	-0.025	-0.033	-0.023	-0.017	0.026	0.034	0.024	0.017
1998-99	-0.028	-0.036	-0.028	-0.019	0.029	0.036	0.028	0.019
1999-00	-0.032	-0.040	-0.032	-0.021	0.033	0.041	0.032	0.022
2000-01	-0.037	-0.047	-0.037	-0.023	0.038	0.048	0.038	0.023
2001-02	-0.040	-0.052	-0.041	-0.023	0.041	0.053	0.041	0.023
2002-03	-0.042	-0.054	-0.042	-0.023	0.043	0.056	0.043	0.023
2003-04	-0.044	-0.058	-0.044	-0.023	0.045	0.059	0.045	0.023
2004-05	-0.043	-0.056	-0.043	-0.024	0.044	0.058	0.044	0.024
2005-06	-0.044	-0.057	-0.048	-0.023	0.045	0.059	0.049	0.023
2006-07	-0.044	-0.059	-0.046	-0.022	0.045	0.061	0.047	0.023
2007-08	-0.042	-0.058	-0.041	-0.024	0.043	0.059	0.042	0.024
2008-09	-0.049	-0.070	-0.050	-0.024	0.051	0.072	0.051	0.024
2009-10	-0.046	-0.063	-0.046	-0.024	0.047	0.065	0.047	0.024
2010-11	-0.047	-0.063	-0.050	-0.025	0.048	0.066	0.052	0.025
2011-12	-0.043	-0.061	-0.040	-0.025	0.044	0.063	0.041	0.025
2012-13	-0.041	-0.057	-0.040	-0.025	0.042	0.058	0.041	0.025
2013-14	-0.040	-0.054	-0.042	-0.023	0.041	0.055	0.043	0.023
2014-15	-0.038	-0.052	-0.038	-0.024	0.039	0.054	0.039	0.024

Source: Author's calculations

Table 8
Decomposition of the absolute change in p_u into the absolute change in p_c, p_p and p_n

Period	∇_{p_u}	∂_{p_c}	∂_{p_p}	∂_{p_n}	Proportionate contribution of the change in		
					p_c	p_p	P_n
1990-91	0.0013	0.0004	0.0004	0.0005	26.8	33.6	39.7
1991-92	0.0013	0.0003	0.0004	0.0005	26.8	34.0	39.2
1992-93	0.0012	0.0004	0.0004	0.0005	29.3	30.6	40.1
1993-94	0.0010	0.0002	0.0003	0.0005	16.6	34.3	49.1
1994-95	0.0015	0.0005	0.0004	0.0005	37.4	28.8	33.8
1995-96	0.0016	0.0007	0.0004	0.0005	40.6	26.0	33.4
1996-97	0.0016	0.0005	0.0005	0.0006	33.6	30.2	36.3
1997-98	0.0018	0.0006	0.0006	0.0006	34.0	30.7	35.3
1998-99	0.0022	0.0009	0.0006	0.0007	39.1	28.6	32.3
1999-00	0.0024	0.0009	0.0007	0.0007	39.0	29.4	31.7
2000-01	0.0026	0.0010	0.0008	0.0008	38.3	30.4	31.4
2001-02	0.0027	0.0010	0.0008	0.0009	37.2	30.5	32.3
2002-03	0.0027	0.0011	0.0008	0.0009	38.7	28.7	32.6
2003-04	0.0025	0.0008	0.0008	0.0009	32.5	31.5	36.1
2004-05	0.0029	0.0012	0.0008	0.0009	41.5	28.5	30.0
2005-06	0.0026	0.0010	0.0008	0.0008	37.4	30.5	32.1
2006-07	0.0025	0.0009	0.0008	0.0008	36.7	30.3	33.0
2007-08	0.0023	0.0008	0.0007	0.0008	34.9	30.3	34.9
2008-09	0.0025	0.0010	0.0008	0.0007	39.1	30.7	30.2
2009-10	0.0020	0.0006	0.0007	0.0007	30.3	32.9	36.9
2010-11	0.0023	0.0010	0.0007	0.0007	41.0	29.1	29.9
2011-12	0.0020	0.0007	0.0006	0.0007	36.7	29.9	33.4
2012-13	0.0018	0.0006	0.0006	0.0006	35.2	30.7	34.2
2013-14	0.0017	0.0006	0.0005	0.0006	34.4	31.4	34.2
2014-15	0.0015	0.0005	0.0004	0.0006	35.0	28.9	36.1
1990-2015	*0.0505*	*0.0181*	*0.0153*	*0.0171*	*35.9*	*30.2*	*33.9*

Source: Author's calculations

Table 9

Decomposition of the inter-country variance in the absolute change in p_u.

$Var(\nabla_{p_u})$=0.0019	Variance-Covariance matrix		
	∂_{p_c}	∂_{p_p}	∂_{p_n}
∂_{p_c}	0.0005	0.0003	0.0001
∂_{p_c}	0.0003	0.0002	0.0001
∂_{p_c}	0.0001	0.0001	0.0001
Contribution to $Var(\nabla_{p_u})$	0.0010	0.0006	0.0003
Proportionate contribution	50.16	33.11	16.73

Table 10
Decomposition of the decrease in the under-five deaths in 190 countries 1990-2015

Components	All	Country groups						
		1	2	3	4	5	6	7
Classification node		7	8	9	10	11	12	6
Number of countries	190	69	41	30	13	22	8	7
Population 1990 (billion)	5.297	1.064	0.640	1.756	0.449	1.217	0.119	0.052
Population 2015 (billion)	7.342	1.238	0.818	2.263	0.723	1.940	0.253	0.103
Birth rate 1990 (per 1000 population)	25.8	14.3	22.4	24.8	32.8	33.6	45.1	46.4
Birth rate 2015 (per 1000 population)	19.0	11.7	17.0	15.2	25.0	23.3	36.1	39.2
p_u 1990	0.908	0.985	0.962	0.938	0.891	0.858	0.804	0.737
p_u 2015	0.958	0.991	0.982	0.977	0.949	0.939	0.935	0.912
p_c 1990	0.970	0.997	0.993	0.984	0.968	0.949	0.913	0.865
p_c 2015	0.989	0.998	0.997	0.995	0.989	0.983	0.973	0.968
p_p 1990	0.972	0.995	0.987	0.981	0.962	0.959	0.930	0.909
p_p 2015	0.988	0.996	0.995	0.993	0.986	0.982	0.981	0.972
p_n 1990	0.963	0.993	0.992	0.971	0.956	0.943	0.946	0.937
p_n 2015	0.981	0.996	0.990	0.990	0.973	0.972	0.974	0.969
Decrease in the number of under-five deaths (∇D) (million)	-6.767	-0.101	-0.297	-1.918	-0.681	-3.050	-0.462	-0.258
Increase in the number of live births (∇L) (million)	2.870	-0.780	-0.433	-9.058	3.350	4.244	3.756	1.791
Increase in the number of live births due to population growth (million)	45.025	2.251	3.462	9.837	7.784	20.055	5.343	2.334

Components	All	Country groups						
		1	2	3	4	5	6	7
Classification node		7	8	9	10	11	12	6
Decrease in the number of live births due to the decrease in birth rate (million)	-42.155	-3.031	-3.894	-18.895	-4.434	-15.811	-1.586	-0.543
Increase in the number of survivors in first five years (∇S) (million)	9.637	-0.679	-0.461	-7.985	3.784	2.089	8.517	4.372
Increase in the number of survivors due to the increase in population (million)	42.000	2.223	3.365	9.410	7.164	18.013	4.667	1.936
Decrease in the number of survivors due to the decrease in birth rate (million)	-39.321	-2.993	-3.786	-18.075	-4.081	-14.201	-1.386	-0.451
Increase in the number of survivors due to increase p_u (million)	6.960	0.091	0.285	1.525	0.948	3.482	0.937	0.563
Increase in the number of survivors due to increase in p_c (million)	2.496	0.018	0.060	0.403	0.316	1.376	0.434	0.297
Increase in the number of survivors due to the increase in p_p (million)	2.104	0.026	0.105	0.419	0.373	0.931	0.326	0.177
Increase in the number of survivors due to the increase in p_n (million)	2.360	0.047	0.120	0.703	0.258	1.175	0.177	0.089

Source: Author’s calculations

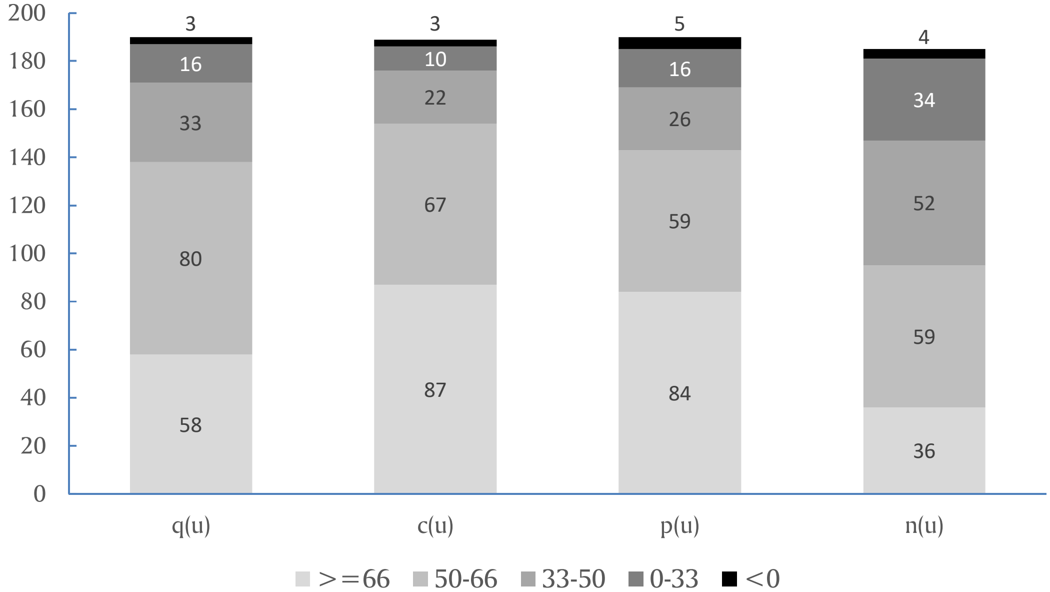

Figure 1: Relative decrease in child mortality (Per cent) in 190 countries, 1990-2015

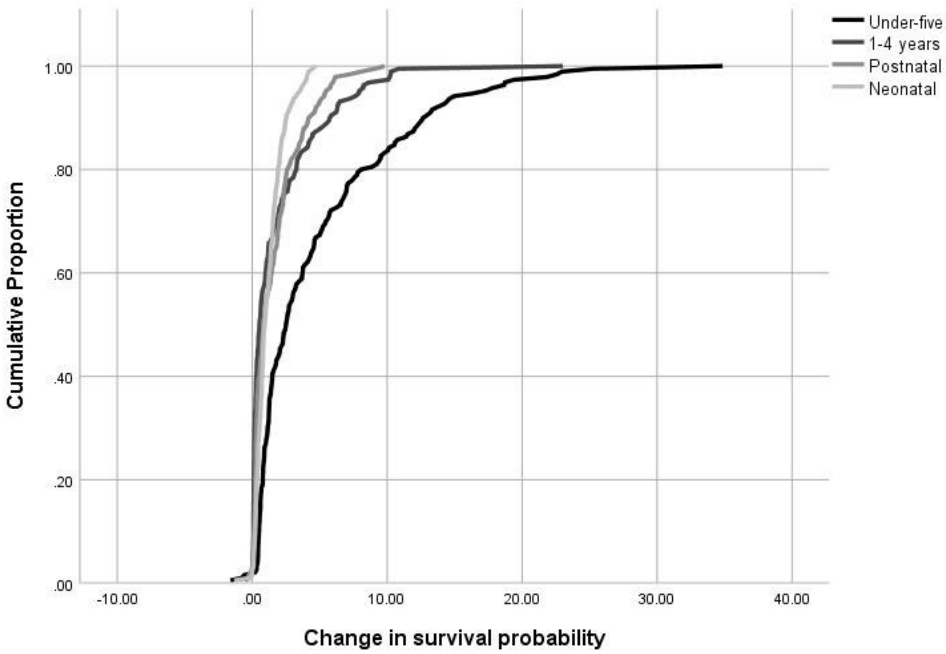

Figure 2: Cumulative distribution of 190 countries in relative increase in child survival probability

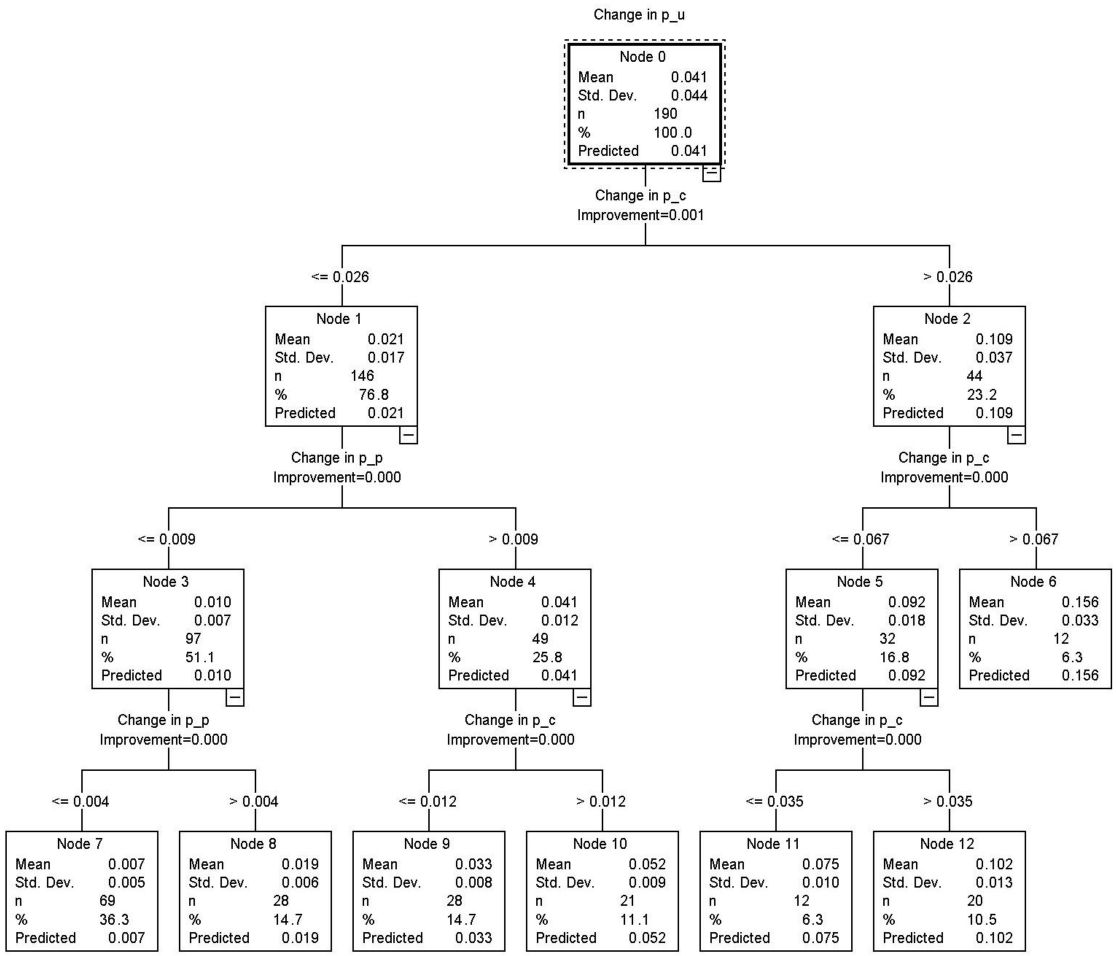

Figure 3: Classification of countries in terms of relative increase in child survival probability

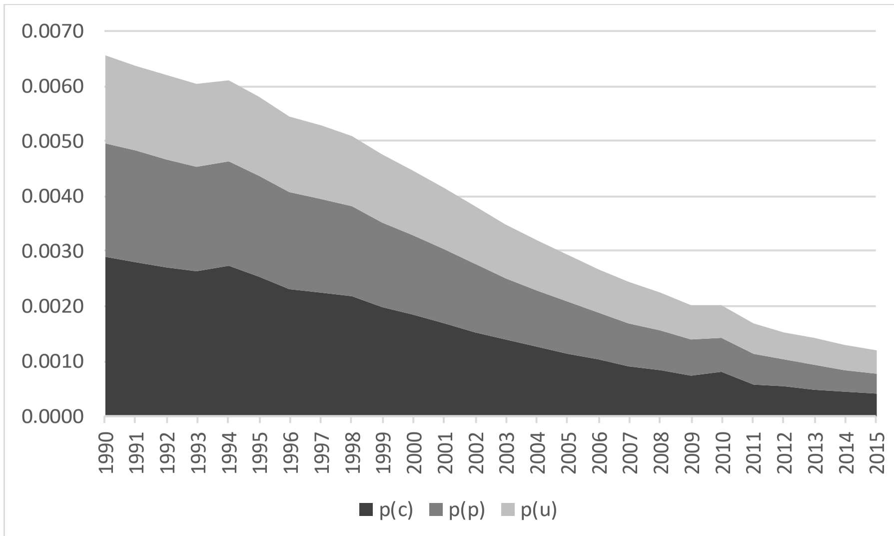

Figure 4: Contribution of inter-country dispersion in p_c, p_p and p_n to p_u, 1990-2015

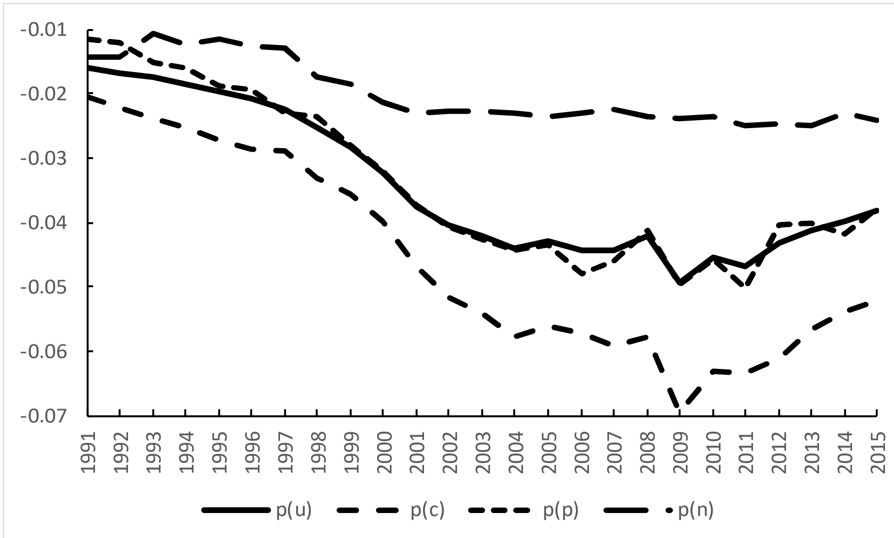

Figure 5: Beta convergence in p_u, p_c, p_p and p_n across countries

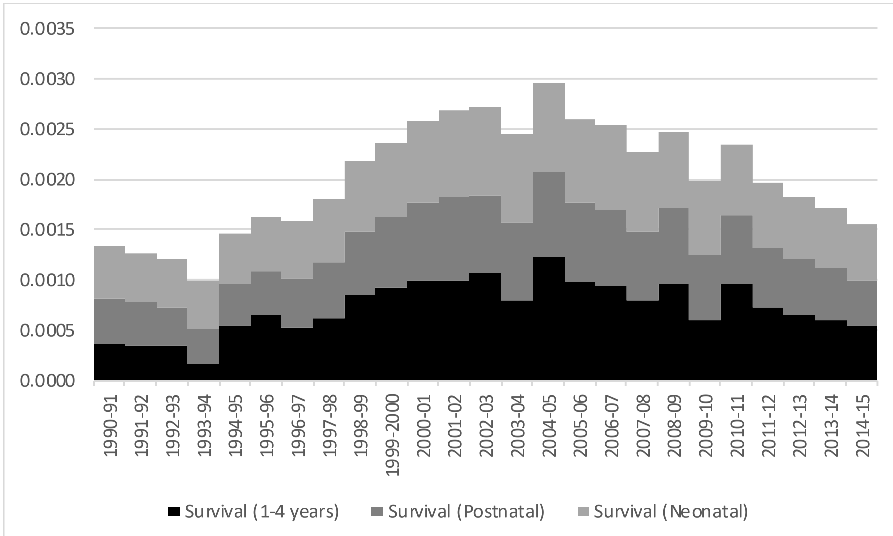

Figure 6: Contribution of the improvement in p_c, p_p and p_n to the improvement in p_u in 190 countries

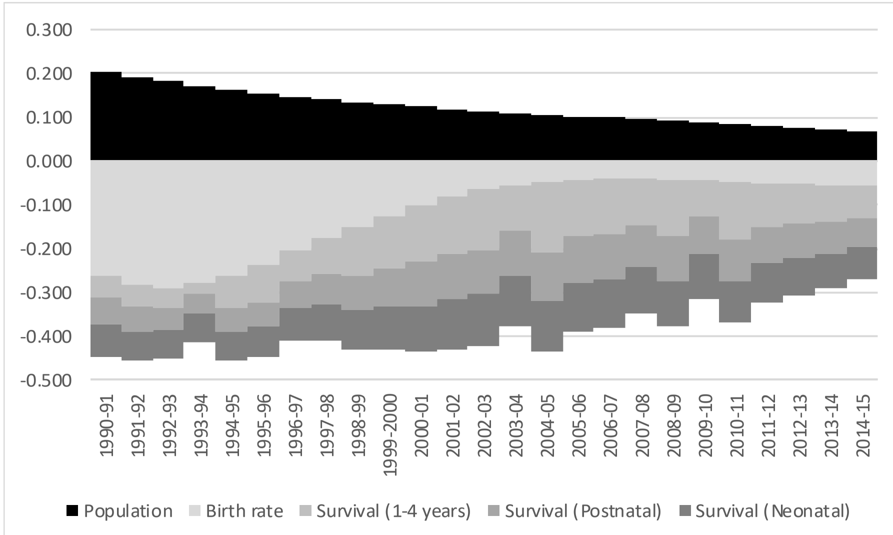

Figure 3: Contribution of the increase in population, fertility transition and increase in child survival probability to the decrease in the number of under-five deaths