Maternal and Child Mortality Indicators across 187 countries in the World: Converging or Diverging

By
Srinivas Goli
International Institute for Population Sciences (IIPS)
Mumbai, India
Email: sirispeaks2u@gmail.com
Phone No: 91+9919892414

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Abstract
This study re-assessed the progress achieved since 1990 in terms of maternal and child mortality indicators to test whether the progress is converging or diverging across the world countries. The convergence process is examined by using standard parametric and non-parametric econometric models of convergence. The results of absolute convergence estimates reveal that progress in maternal and child mortality indicators are divergent for entire period (MMR—β=.00033, p<0.574; NNMR—β=.04367, P<.000; PNMR—β=.02677, p<.000; U5MR—β=.00828, p<.000). In the recent period, such divergence is replaced with convergence for MMR but increased for all the child mortality indicators. The results of kernel density estimate reveal considerable reduction in divergence for MMR in the recent period; however, the Kernel density distribution is with more than one “peak” which indicates the emergence of convergence clubs based on their mortality levels. For all the child mortality indicators, the kernel estimates suggest a divergence in the progress across the countries worldwide but convergence in countries with low mortalities. A mere progress in global averages of maternal and child mortality indicators across the countries do not warranty the convergence unless there is a considerable reduction in variance, skewness and range of change.

Keywords: Maternal mortality; Child mortality; Convergence; Divergence; World countries

Introduction
Maternal and child health is arguably the heart of the MDGs (Lawn et al. 2006). The World has barely three and half years left to accomplish the Millennium Development Goals (MDGs) of reducing maternal and child mortality to the targeted level. In the past two decades, ‘maternal, newborn and child health subjects were engrossing, debatable, and fast moving as people pay greater attention to these subjects, the data are evolving and, on a positive note, the deaths are falling’ (Ehiri 2010). Maternal and child mortality are two of eight goals for development adopted by 189 countries in the Millennium Declaration in 2000. Millennium Development Goal5 (MDGs5) set the ambitious target to reduce the maternal mortality ratio by three-quarters during 1990-2015. Similarly, Millennium Development Goal4 (MDGs4) aims to reduce under5 mortality rate by two-thirds during the same period (United Nations 2010). These two issues have prompted the global health analysts and driven increased levels of development aid, policy attention, and research work (Goodburn and Campbell 2001, Child Mortality Coordination Group 2006, Starrs 2006, Hill et al. 2007, Murray et al. 2007, Countdown Coverage Writing Group on behalf of the Countdown to 2015 Core Group 2008, Gregson et al. 2009, Hogan et al. 2010, Rajaratnam et al. 2010).
The estimates of Maternal Mortality Ratios (MMRs) during 1990 to 2008 for many countries reveals, for the first time, a substantial decline of 30-45 percent in number of annual maternal deaths worldwide (Hogan et al. 2010, Rajaratnam et al. 2010, Yadamsuren 2010, Lozano et al. 2011). Hogan et al. (2010) has reported “globally maternal deaths have dropped from an estimated 526,300 in 1980 to 342,900 in 2008. Since 1990, the annualised rate of decline in the maternal mortality ratio has been 1.3 percent, dropping to 251 deaths per 100,000 live births in 2008”. Another study, by Rajaratnam et al. (2010) reported “Worldwide mortality in children younger than 5 years has dropped from 11.9 million deaths in 1990 to 7.7 million deaths in 2010, consisting of 3.1 million neonatal deaths, 2.3 million post neonatal deaths, and 2.3 million childhood deaths (deaths in children aged 1-4 years). The global decline from 1990 to 2010 is 2.1 percent per year for neonatal mortality, 2.3 percent for post neonatal mortality, and 2.2 percent of childhood mortality. Among the 13 regions of the world, including all regions in sub-Saharan Africa, there is evidence of accelerating declines from 2000 to 2010 compared with 1990 to 2000. Similarly, the under5 mortality rate declined 2.1 percent annually during 1990 to 2008, and the death rate for the post neonatal phase between 1 month and 1 year of age declined 2.3 percent”.

However, a recent United Nations report (2010) on MDGs evaluation suggests “though progress has been made, it is uneven. Moreover, without a considerable push forward, many of MDG targets are likely to be missed out in most regions. Old and new challenges threaten to further slow progress in some areas or even undo the successes achieved so far”. WHO et al. (2012) also reported “nearly 80 percent of all maternal deaths in 2008 crop up in just 21 countries, and half of all maternal deaths are occurred in six countries: India, Nigeria, Pakistan, Afghanistan, Ethiopia, and the Democratic Republic of the Congo”. “A comparison of maternal mortality rates in Canada and Afghanistan reveal that Canada has one of the lowest in the world, with 7 deaths per 100,000 live births in 2008, whereas the Afghanistan’s maternal mortality rate was 1575 deaths per 100,000 live births in 2008” (Mac Arthur Foundation 2010). The rates of change in the maternal mortality ratio vary widely across countries, “from an annualised decline of more than 8 percent in the Maldives to an increase of 5.5 percent in Zimbabwe during 1990 to 2008. Moreover, only 31 developing countries in the world are likely to meet the MDG 4 goal in case of child mortality indicators” (Rajaratnam et al. 2010).

The recent reported anomalies in progress of maternal and child mortality indicators, developed a curiosity to test the convergence hypothesis across 187 countries worldwide in terms of maternal and child mortality indicators. Though, earlier studies such Hogan et al.
(2010), Rajaratnam et al. (2010), Yadamsuren (2010), Lozano et al. (2011) and WHO et al. (2012) are presented ideal assessment of progress in terms of maternal and child mortality indicators across the world countries and reported remarkable progress in these two indicators. However, none of these studies have tested quantitatively whether, such progress is reflected in convergence and at what speed the gap is closing in terms of absolute convergence in maternal and child mortality indicators for the 187 world countries.

Numerous studies have suggested that the global progress in demographic and public health indicators do not warrant convergence across countries (Neumayer 2004, McMichael et al. 2004, Becker et al. 2005; Moser et al. 2005, Dorius 2008, 2010 etc.). Theoretically, following homogeneous pre-transition phase of health transition, progressive transition generates multidimensional geographic heterogeneity, until the reappearance of a homogeneous post-transition phase (Oeppen, 1999). Based on this perspective, some studies have assessed the progress of health indicators at global and local level, and supported the divergence hypothesis during initial and progressive stage of the health transition, then followed a convergence. Few studies also suggested recent setbacks in convergence of life expectancy at birth across the countries worldwide (Neumayer 2004, McMichael et al. 2004, Becker et al. 2005; Moser et al. 2005, Bloom and Canning 2007, Dorius 2008, 2010, Clark 2011, Gächter and Engelbert 2011). Testing a convergence hypothesis reveal whether, the reported progress in global averages of maternal and child mortality indicators is contributed from few developed countries or all world countries. According Solow (1956) growth model, “if the progress is greater among the developing countries than the developed countries it leads to convergence across the world countries. On the contrary, if the progress greater among the more developed countries, it widens the already existing gaps which leads to divergence across the world countries” (Barro and Sala-I-Martin 1991). Therefore, it is crucial to test a convergence hypothesis to see whether the reported progress in maternal and child health indicators is converging or diverging. Hence, the fundamental research question of this study is to assess whether the progress in maternal and child mortality indicators in the recent decades is reflected in convergence or divergence across the 187 countries of the world.

**Methods**

**Data Source**

This study used a compiled data base documented in a report titled “Building Momentum: Global Progress toward Reducing Maternal and Child Mortality” by Hogan and colleagues
(2010) from the Institute for Health Metric Evaluation (IHME), Seattle, United States of America (USA). This study considered four maternal and child health indicators: Maternal Mortality Ratio (MMR), Neonatal Mortality Rate (NNMR), Post Neonatal Mortality Rate (PNMR) and Under5 Mortality Rate (U5MR) for assessing convergence in progress across the world countries. MMR is measured as ‘maternal deaths per 100000 live births’ and all child mortality indicators are measured as ‘child deaths per 1000 live births’.

Maternal mortality estimates of Hogan and Colleagues consider being more robust compared to other available estimates. Though, Hogan and colleagues constructed a dataset based mainly on the WHO mortality database but it was supplemented by the systematic review of various sources of data on maternal mortality and classified them into four types: vital registration systems; sibling history data from household surveys; data from censuses and surveys for deaths in the household; and published work reporting population-based studies of maternal mortality, both national and sub-national. Several issues with vital registration data have taken into consideration: First, periodic changes in the ICD rules and codes can lead to discontinuities that are not an indication of true trends. Second, the estimates were adjusted for misclassification of maternal deaths. Third, they have analysed sibling history microdata from the DHS and International Reproductive Health Surveys. Fourth, they undertook a literature review to identify published estimates of maternal mortality including all citations in the WHO publication ‘Maternal Mortality: a Global Factbook’ to cross-check the results.

Childhood mortality rates were estimated from the pooled data of Demographic and Health Surveys (DHS). The pooling approach mitigates some of the concerns of bias in the complete birth histories, such as selection bias for surveys in the countries with high prevalence of HIV. However, if microdata were not available, they obtain tabulated data for children who died and children ever born by mother’s age and applied the maternal age cohort-derived method. If microdata or tabulated data were not available, they included estimated values of childhood mortality rates from DHS reports. They adjusted estimates on the basis of household deaths from single surveys by use of the growth balance method. When completeness of death reporting was estimated to be more than 100%, they adjusted the death rates downwards, with the logic that respondents might be telescoping deaths—i.e., including deaths that occurred outside the recall period in the period of recall. They used two criteria for identifying outliers: rates of child mortality that were far beyond the plausible range in view of a country’s level of development, and rates of child mortality that were substantially inconsistent with other sources of information for the same country that cannot
be explained by a known mortality shock (for more details, see Hogan et al. (2010) and Rajaratnam et al. (2010).

Convergence metrics

The study used three types of convergence metrics: First, the two-way scatter graphical plots are used to examine the catching-up process. Second, volume and speed of convergence is calculated by using standard parametric econometric models of convergence such as absolute β-convergence and σ-convergence. Third, non-parametric econometric models of convergence such as Kernel density estimates and plots are also used to explain the convergence clubs. The detail specifications of the methods used in this study are given below.

Catching-up process: Before estimating the β or σ-convergence, this study assessed the catching-up process, which is a necessary pre-condition for β-convergence. The catching-up process is assessed through two-way scatter plots that, the change in maternal and child mortality indicators ‘y’ as against their initial levels ‘x’. The catching-up process indicates that greater change in laggard countries compared to advanced countries.

Though, scatter plots showing catching-up mechanism do provide some evidence on the process of convergence but not enough to prove or quantify convergence. Therefore, testing of the convergence hypothesis with an appropriate convergence model is must. Moreover, few of the previous studies also reported that during the period of progressive transition, in spite of considerable change or progress, the indicators may not experience convergence; instead they can indicate divergence (Neumayer 2004, Dorius 2008). Therefore, this study further used convergence metrics to test convergence hypothesis.

Absolute β-convergence: Among standard parametric analyses of convergence, this study is used absolute β-convergence measure as a method of convergence analyses. An assessment of β-convergence tells whether, the catching-up process of laggard countries with advanced countries in selected indicators is resulting into convergence or not. Absolute β-convergence is used where the gap between the rich and poor countries shrinks especially due to greater progress in laggard countries, a concept that originated from the work of Barro and Sala-i-Martin (1991). In this study, absolute convergence was tested using the following linear regression model specified in Rely and Montouri (1999):

\[
\ln \left( \frac{Y_{i,t+h}}{Y_{i,t}} \right) = \alpha + \beta \ln(Y_{i,t}) + \varepsilon_{it}
\]
Where $\ln \left[ \frac{Y_{i,t+k}}{Y_{i,t}} \right]$ is the mean annualized growth rate of the variable $Y$ in country $i$ in the period $(t, t+k)$, $Y_{i,t}$ is the value in the initial time $t$ and $\epsilon_{i,t}$ are corresponding residuals. The speed of convergence is computed as $s = -1/T \ln (1+T\beta)$. Where, $s= speed of convergence$ and $T\beta$ is the $\beta$-convergence in $T$ period.

According to Dorius (2008), “the long term assessments of convergence sometimes hide trends in convergence for sub-periods. From a policy perspective, progress in recent periods is much important”. Therefore, this study also estimated piece-wise absolute $\beta$-convergence by disaggregating the entire period (1990 to 2008) into two parts (1990 to 2000 and 2000 to 2008).

$\sigma$-convergence: Another standard parametric econometric model of convergence is $\sigma$-convergence (Friedman 1992, Quah 1993a), usually measured either by the standard deviation or the coefficient of variation in two different periods of time. The measurement of $\sigma$-convergence assumes importance because the presence of a $\beta$-convergence will not give a warranty of $\sigma$-convergence. As explained by Quah (1993a), the $\beta$-convergence is necessary but not sufficient to achieve the $\sigma$-convergence, and consequently $\beta$-convergence should be complemented by the analysis of $\sigma$-convergence (Sala-i-Martin 1996, Young et al. 2008, Dorius 2008, 2010). Indeed, Quah (1993a) and Freedman (1992) both suggest that $\sigma$-convergence is of greater interest since it speak directly as to whether the distribution of an indicator across the countries is becoming more equitable or not? Therefore, this study is also used $\sigma$-convergence measure as a method of convergence analyses. Through, $\sigma$-convergence analyses it is possible to find if maternal and child mortality indicators are becoming increasingly similar across the countries or not? Friedman (1992) considers that the true test of $\sigma$-convergence is a decline in the variance among individual observations. $\sigma$-convergence is estimated by using Coefficient of Variation (hereafter CV). CV is estimated as

$$CV = \frac{\sigma_z}{\mu}$$

Where $\sigma_z$ is the standard deviation (or assimilated measure) of the indicator at the time $t$. $\mu$ is the mean of the indicator. If the parameter $CV_{t+T}$ declined over time, it implies convergence.

Though, parametric convergence metrics are widely used to examine the convergence process, but non-parametric methods offer alternative approaches to the analysis of the convergence process. Among non-parametric convergence metrics, histogram density
estimates and kernel density estimates are widely used methods. While later is closely related to histograms, but can be endowed with properties such as smoothness or continuity by using a suitable kernel. The smoothness of the kernel density estimate is better interpreted compared to the discreteness of the histogram as kernel density estimates converge faster to the true underlying density for continuous random variables” (Scott 1979). Therefore, in the second stage we used Kernel density estimates. Kernel density estimates allow a closer look at changes in the distribution in relative terms. They allow data to be modelled without presuming that the data follow a normal distribution and identify the short-term divergent paths, which may occur in long convergence process (Quah 1993a). Further, kernel density estimator is the best suitable test for identifying the number of clusters of MMR and childhood mortality. The advantage of kernel density estimators is that the clusters are not prejudiced by geographical regions (which prone to huge heterogeneity within the region) rather they are emerging from the distribution of the prevalence of MMR and childhood mortality. This study is used the Epanechnikov kernel which is an optimal in a minimum variance sense (Epanechnikov 1969). We used this adaptive bandwidth kernel density estimation. If the bandwidth is not held fixed, but is varied depending upon the location of either the estimate (balloon estimator) or the samples (pointwise estimator), this produces a particularly powerful method termed bandwidth kernel density estimation. We used this adaptive bandwidth kernel density estimation. This will make estimates more robust and will not affect the results.

A general form of kernel densities is estimated by using the following equation:

\[ f(x) = \frac{1}{hn} \sum_{i=1}^{n} k\left(\frac{\frac{x-x_i}{h}}{n}\right) \]

Where, \( f(x) \) is the density estimation of the variable x, n is the number of observations, h is the bandwidth (smoothing parameter) and K (.) is the smooth and symmetric kernel function integrated to unity.

**Results**

**Descriptive statistics**

Table 1 presents summary statistics of maternal and child mortality indicators for the period 1990 to 2008. Results show that total number of samples in selected indicators are same for all the three periods. Among 189 countries taken the pledge for MDGs, the data on maternal and child mortality indicators are available for 187 countries with seven missing cases for
MMR. Therefore, the total sample for MMR is 180 for all periods. However, the data are available for 187 countries for all the child mortality indicators. The global mean MMR has declined from 280 per 100 000 live births to 214 per 100 000 live births during 1990 to 2008. The standard deviation of MMR across the 180 world countries is increased from 344 per 100 000 live births to 383 per 100 000 live births in the initial period, 1990 to 2000, but drastically dropped (383 per 100 000 live births to 302 per 100 000 live births) in the recent period, 2000 to 2008. The similar pattern is also evident in case of a Range of MMR across 180 world countries.

For all the child mortality indicator estimates of mean, standard deviation and range are showing a declining trend during 1990 to 2008. The global mean of NNMR is 24 per 1000 live births in 1990 and has declined to 16 per 1000 live births in 2008. The standard deviation of NNMR has also declined from 17 per 1000 live births to 13 per 1000 live births during 1990 to 2008. A similar pattern is observed in case of PNMR and U5MR. In case of PNMR, the global mean has declined from 23 per 1000 live births to 14 per 1000 live births during 1990 to 2008, and in the same period the standard deviation also declines from 22 per 1000 live births to 15 per 1000 live births. Global mean and standard deviation of U5MR decline by 30 per 1000 live births and 20 per 1000 live births respectively, in the period of 18 years.

**Catching-up process**

Figure 1 shows the scatter plot of the change in MMR by MMR in the initial period from 180 world countries during 1990 to 2008. The results show a mixed pattern of change and catching-up process in terms of maternal and child mortality indicators. Though, few of the laggard countries (which show higher mortality rates in the initial period) shows considerable improvement in MMR, but a considerable number of states show either no change or negative change. However, in case of all the child mortality indicators the results evident a clear catching up process with greater changes in laggard countries compared to the advanced countries (Figure 2, 3, 4). At the same time, few countries' experience zero change or negative but those numbers are very small compared to countries which are experiencing better change in MMR. Overall, three types of progress are noticed from laggard countries (Figure 1, 2, 3, 4). First set of countries experiencing the catching-up mechanism with greater progress in maternal and child mortality indicators. A second set of countries have experienced slow progress; therefore, these countries are yet to pick up the progress to initiate the catching-up mechanism. A third set of countries are either stagnant or experiencing
negative progress. With these three patterns of progress across 187 countries may or may not be necessarily results into convergence.

**Absolute β-convergence model estimates**

Table 2 presents the results of absolute β-convergence model for MMR across the 180 world countries. The results reveal that during the last two decades the progress in MMR is divergent (β=. 00033, p<0.574) across the world countries. The piece-wise absolute β-convergence estimates also indicate statistically significant divergence (β=.00220, p<0.007) in the progress of MMR across world countries for the base period, 1990 to 2000, but for the recent period, 2000 to 2008, the earlier divergence is replaced with significant convergence (β= -.00113, p<0.027). The speed of convergence estimates shows that progress in MMR across the world countries is converging at the rate of 0.11 percent per year during 2000 to 2008.

In spite of considerable catching-up process shown by scatter plot analyses, the absolute β-convergence estimates for neonatal mortality rate in table 3 show evidence of significant divergence (β=.04367, p<.000) in the progress of neonatal mortality rate across the world countries for the entire period under observation, 1990 to 2008 and for the sub periods, 1990 to 2000 and 2000 to 2008. However, the convergence estimates for the sub periods indicate greater divergence (β=.05584, p<.000) in 2000 to 2008 compared to 1990 to 2000 (β=.04678, p<.000). The speed of convergence estimate also shows that the divergence is greater and statistically significant in 2000 to 2008 (4.6 percent) than 1990 to 2000 (3.84 percent).

Convergence estimates in table 4 and 5 also evident divergence in progress of post neonatal mortality rate (β=.02677, p<.000) and under5 mortality rate (β=.00828, p<.000) across the 187 countries during 1990 to 2008. Further, results show that the model estimates are statistically significant. Akin to neonatal mortality rate, the results for post-neonatal and under-five mortality rates also reveal that divergence is more in 2000 to 2008 (β=.04225, p<.000 and β=.011066, p<.000, respectively) than 1990 to 2000 (β=.02820, p<.000; β=.00968, p<.000, respectively). The speed of convergence estimates for neonatal, postnatal and under5 mortality rates also show that the rate of divergence (−4.62 percent, −3.64 percent, −1.06 percent, respectively) is more in 2000 to 2008 compared to 1990 to 2000 (−3.22, −2.18, −0.77).

**σ-convergence model estimates**
Figure 5 shows the trends in CV in maternal and child mortality indicators, in 187 world countries, during 1990 to 2008. The trends of CV in MMR, in world countries show that, the world became more dissimilar in terms of progress in reduction of MMR in 2008 than 1990. However, observation of disaggregated trends indicates that, the increase of CV in MMR of world countries is sharper in 1990 to 2000 (0.14 points) compared to 2000 to 2008 (0.04 points). In the literature, the increase in CV in MMR considered to be divergent progress (Dorius, 2008). However, the rate of divergence in MMR progress is decreased (0.14 in 1990-2000 compared to only 0.04 in 2000-2008) for the recent period, 2000 to 2008.

The trends of CV for world countries in terms of NNMR show a considerable increase (0.79 in 2008 compared to 0.68 in 1990) during 1990 to 2008. The rate of divergence in two disaggregated periods, 1990 to 2000 and 2000 to 2008 show that, in both the periods the increase in CV in NNMR, across the world countries more or less same and suggesting divergence in progress of NNMR. Similar results also evident in case of PNMR of world countries. The trends of CV in PNMR of world countries show, a steep increase during 1990 to 2008. In a period of 18 years, the CV increased by 0.14 points (0.91 in 1990 to 1.06 in 2008). The estimates of CV in UN5M of world countries indicate a steep increase (0.07 points) during 1990 to 2000, but in post-2000 it increased with decreased slop (0.02 points). Overall for all the child mortality indicators, σ- convergence estimates suggest a divergence hypothesis during 1990 to 2008.

**Kernel density estimates**

Figure 6 presents the univariate kernel density estimators and density plots showing the distribution of maternal and child mortality indicators across world countries. The first rows of the figure 6 show that the distribution of MMR across the world countries for the years 1990, 2000 and 2008. In 1990, the plots indicate that a bimodal distribution of MMR across the world countries. However, the mode on the left side with high peak is located at the lower values of MMR=500 per 100000 live births and a small peak are located in the values of the MMR range from 500 to 600 per 100000 live births. A bimodal distribution with “two peaks” is referred in literature as “convergence clubs” (Quah, 1996). However, in 2000, the second peak has appeared in plateau shape at MMR values range from 500 to 1000 per 100000 live births, this clearly indicate a divergence in MMR across the countries. In 2008, with narrowing distribution particularly among those countries with low MMR values and the disappearance of any significant secondary peaks indicates an emerging convergence process in MMR across the world countries.
The second row of the figure 6 shows the univariate kernel density estimators and density plots for NNMR at three points of time, 1990, 2000 and 2008. A comparative assessment of three periods shows narrow dispersion in the first pic but the emergence of “two peaks” and rise in the height of the second peak for the latest year, 2008 evident for divergence in NNMR across the countries. However, it also indicates the convergence across two different clubs of countries: one is at low level (NNMR<20 per 1000 live births) and second is between NNMR 25 to 35 per 1000 live births. The results for postnatal mortality also present the similar evidence: the distribution across the countries is slightly narrowed in 2008 compared to 1990. However, there is not any clear evidence of convergence; rather it seems to be the emergence of bimodality in the year, 2008 which evident for the presence of convergence clubs.

The last row of the figure 6 presents the univariate kernel density estimates for under-five mortality rates for the year, 1990, 2000 and 2008. The plots indicate that though the distribution of under-five mortality is narrowed in 2000 compared to 1990, but the dispersion in the distribution of under-five mortality is stagnant during 2000-2008. There is no clear evidence of bimodality or multimodality, but the distribution in under-five mortality is not very smooth; thereby showing any evidence of absolute convergence.

Reasons for convergence in MMR and divergence in Child mortality rates
Table 6 presents the variance, skewness and range of change in maternal and child mortality indicators during 1990 to 2008. The results clearly present that convergence in MMR for recent decade, 2000 to 2008 is driven by more than 50 percent decline in variation (28764 to 11764) and range of change (1583 to 696), and considerable increase in skewness (-1.49 to 2.28) of change across the countries in between 1990- 2000 to 2000-2008. However, in the same period, the decline in variance of change in child mortality indicators across the countries is less in comparison to the change observed in MMR. Moreover, for two out of three child mortality indicators results evident that the range of change is virtually stagnant. Moreover, for all the child mortality indicators, the increase in the skewness of change is less in comparison to the change witnessed in the case of MMR. Thus, indicate that there is unequal progress across countries in spite of the remarkable decline in global averages of child mortality indicators during 1990 to 2008.
Discussion

Testing of the convergence hypothesis for trends in maternal and child mortality indicators during 1990 to 2008 by using three different types of convergence metrics point out discrepancies in the progress achieved in terms of MDG4 and 5. Though, the graphical assessment indicates clear evidence of catching-up process for all the maternal and child mortality indicators, but the model estimates show lack of convergence. The results of the absolute β-convergence estimates suggest a divergence in the progress of the MMR across the world countries for the entire period and convergence for the recent period. The progress in all child mortality indicators is divergent and such divergence has increased in the recent period. The results of σ-convergence estimates suggest divergence in progress of MMR and child mortality indicators across the world countries during the entire period, 1990 to 2008 and sub-periods, 1990 to 2000, 2000 to 2008. However, the speed of divergence is slightly decreased for MMR and under-five mortality rates during 2000 to 2008. The kernel density estimates and plots also support the results of σ-convergence estimates that the observed divergence process for MMR and child mortality indicators for the entire period but observed reduction in the speed of divergence for the MMR during 2000 to 2008. However, the emergence of more than one “peak” in kernel density distribution is the indication of presence of convergence clubs. This implies that the though, there is no evidence for clear convergence process on a global scale but the countries are converging in different clusters based on the mortality levels. Convergence clubs located among countries with the two different levels of mortality: the first club is among the countries with low mortality levels (about <300 for MMR, <20 for NNMR and PNMR, <50 for UN5M) and second club is among the countries with high mortality levels (between 500-1000 for MMR, 20 to 40 for NNMR and PNMR, 100 to 200 for UN5M). However, the highest “peaks” of the kernel density distribution for all the selected variables are located at lower levels which implies that a larger number of countries clustered at mortality levels <300 for MMR, <20 for NNMR and PNMR, <50 for UN5M (Figure 6).

Overall, the results also suggest that there are no doubts in the fact that there is a considerable progress in global averages of both maternal and child mortality indicators as observed in previous studies (Starrs 2006, Hill et al. 2007, Gregson et al. 2009, Hogan et al. 2010, Rajaratnam et al. 2010, Yadamsuren 2010, Lozano et al., 2011 etc.). However, a mere progress in maternal and child mortality indicators do not warranty the convergence unless the dissimilar progress across different clubs of the countries is monitored by effective health
interventions. For policy perspective, it is beneficial to find the reasons of convergence or divergence. Therefore, this study also assessed the reasons for recent emerging convergence in global MMR and divergence, in child mortality indicators. The reasons assessed in this study also foster an idea that some countries progressing much faster compared to other countries. The uneven progress within the laggard countries in MMR during 1990-2000 is led to divergence. During this period, 46 out of 180 countries experienced negative change due to increase in MMR in 2000 in comparison with MMR levels in 1990. Many of these countries belong to sub-Saharan Africa and Central Asia. However, the situation has changed in 2000-2008, where only 11 countries have experienced an increase in MMR. Moreover, the level of increase in MMR is insignificant compared to the level of increase observed in 1990-2000. Thus, the emerging convergence or reduction in divergence in MMR for the recent period is attributable to the dramatic decline in variance and skewness of progress in MMR across the world countries. Contrastinglly, greater divergence in the recent decades for child mortality indicators shows that some countries have accelerated progress while few countries are virtually stagnant. For instance, the progress achieved in many of the countries of the sub-Saharan Africa and Central Asia is less in comparison with other developed and developing countries. Moreover, the skewness of change in child mortality indicators across the world countries showed very less improvement which could be a strong reason for the recent divergence in these indicators (table 6). Moreover, the literature on maternal and child health indicators foster that the change starts with maternal health and reflects on child health (Starrs 2006, Murray et al. 2007). Therefore, followed by MMR, in the near future we can also observe the reduction in the divergence in progress of child mortality indicators too.

In conclusion, this study foster that the global trends in average maternal and child mortality indicators show the momentum towards development. However, inter-country discrepancies and relative levels of progress is growing interest on recent health policy agenda across the world. Many of the recent studies focused on maternal and child mortality have not attempted to quantify the discrepancies in progress (Starrs, 2006; Hill et al. 2007; Gregson et al., 2009; Hogan et al., 2010; Rajaratnam et al., 2010; Yadamsuren 2010; Lozano et al., 2011 etc.). Using sophisticated econometric tools to assess the progress in health indicators is a welcome step. This study for the first time assessed progress in maternal and child mortality indicators across 187 countries by using both parametric and non-parametric measures of convergence. Therefore, this study fills a critical research gap by testing convergence hypothesis for 187 countries in terms of maternal and child mortality indicators.
As evident in terms of other indicators, Neumayer (2004) and Dorius (2008) foster that during the progressive transition, divergent progress is inevitable because the steady state of different countries in terms of their socioeconomic conditions, prevailing policy and resource constraints led to a difference in the rate of progress. This indicates that though, many of countries across the world made an effort to eradicate excess and avoidable maternal and child mortality. The progress in some countries is tremendous, but in few countries it is either yet to pick-up or stagnant or reversing (Table 6). However, a strong programme intervention to bring equity with efficiency can override this consequence. Thus, the findings of the study foster a strong policy message that health policy need to focus on efficiency but with equity because though, both developed, and developing countries are progressing in terms of maternal and child health, but there is a large gap between these two groups, which must be reduced. Therefore, the strategies focusing to eradicate avoidable maternal and child mortality have needed to focus on not only on the progress or change, but also on the convergence of such progress across the world-wide countries.

Though, such efforts need identification of challenges in view of achieving MDGs 4 and 5 in the laggard countries and greater efforts in terms of maternal and child health services. A country specific intervention strategy is to be adopted to improve maternal and child health in laggard countries. These countries should receive adequate investment, especially from local governments. Still, the public health spending on primary health care in the majority of the developing countries is far below that of many developed countries (Hopkins, 2010). A strong commitment from local governments is needed to accelerate progress in order to catch-up not only the MDGs, but the levels and standards set by other developed countries in terms of maternal and child health. Global agencies and leaders need to identify the backbenchers in terms of progress and act as a creator to push forward and accelerate progress in maternal and child health. Unless the laggard countries scale-up the maternal and child health coverage interventions to create acceleration in the catching-up process, it is difficult to achieve convergence in the reduction of child mortality indicators across world-wide countries. Convergence measures can be used as a tool for measuring and monitoring of equitable and sustainable progress of health outcomes.

References


Figure 1. Change in MMR (per 100000) by MMR in initial period for 180 world countries, 1990-2008.

Figure 2. Change in NNMR (per 1000) by NNMR in initial period for 187 world countries, 1990-2008.
Figure 3. Change in PNMR by PNMR in initial period for 187 world countries, 1990-2008.

Figure 4. Change in under five mortality rate by under five mortality rate in initial period for 187 world countries, 1990-2008.
Figure 5. Trends in coefficient of variation (c.v.) in maternal and child mortality indicators in 187 world countries, 1990-2008.
Figure 6. Kernel Density estimation and curves of maternal and child mortality indicators for 187 world countries, 1990-2008.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Time points</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev</th>
<th>Min</th>
<th>Max</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMR</td>
<td>1990</td>
<td>180</td>
<td>280.24</td>
<td>343.72</td>
<td>6</td>
<td>1757</td>
<td>1751</td>
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<tr>
<td></td>
<td>2000</td>
<td>180</td>
<td>279.62</td>
<td>382.89</td>
<td>5</td>
<td>1988</td>
<td>1983</td>
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<tr>
<td></td>
<td>2008</td>
<td>180</td>
<td>214.88</td>
<td>302.49</td>
<td>4</td>
<td>1575</td>
<td>1571</td>
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<tr>
<td>NNMR</td>
<td>1990</td>
<td>187</td>
<td>24.5</td>
<td>16.6</td>
<td>3</td>
<td>70</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>187</td>
<td>19.74</td>
<td>14.47</td>
<td>2</td>
<td>63</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>2008</td>
<td>187</td>
<td>16.18</td>
<td>12.71</td>
<td>1</td>
<td>58</td>
<td>57</td>
</tr>
<tr>
<td>PNMR</td>
<td>1990</td>
<td>187</td>
<td>23.66</td>
<td>21.64</td>
<td>2</td>
<td>96</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>187</td>
<td>18.11</td>
<td>17.89</td>
<td>1</td>
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<td>77</td>
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<tr>
<td></td>
<td>2008</td>
<td>187</td>
<td>14.02</td>
<td>14.83</td>
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<td>64</td>
<td>63</td>
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<tr>
<td>UN5M</td>
<td>1990</td>
<td>187</td>
<td>70.08</td>
<td>65.42</td>
<td>7</td>
<td>297</td>
<td>290</td>
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<tr>
<td></td>
<td>2000</td>
<td>187</td>
<td>54.37</td>
<td>54.25</td>
<td>4</td>
<td>224</td>
<td>220</td>
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<tr>
<td></td>
<td>2008</td>
<td>187</td>
<td>43.87</td>
<td>44.95</td>
<td>3</td>
<td>180</td>
<td>177</td>
</tr>
</tbody>
</table>

Note: Obs-observations, Std.Dev-Standard Deviations, Min-Minimum, Max-Maximum

Table 2. $\beta$ Convergence estimates for Maternal Mortality Rate (MMR) across the 187 countries of the world, 1990-2008.

<table>
<thead>
<tr>
<th>Period</th>
<th>$\beta$ coefficient</th>
<th>P value</th>
<th>Adjusted $R^2$</th>
<th>Speed of convergence (in % per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-2008</td>
<td>.00033 (.00058)</td>
<td>.574</td>
<td>.004</td>
<td>-.03</td>
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<tr>
<td>1990-2000</td>
<td>.00220 (.00080)</td>
<td>.007</td>
<td>.035</td>
<td>-.22</td>
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<tr>
<td>2000-2008</td>
<td>-.00113 (.00050)</td>
<td>.027</td>
<td>.021</td>
<td>0.11</td>
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</tbody>
</table>

Note: n=180, df=179, Heteroscedasticity-consistant standard error are reported in parentheses.

Table 3. $\beta$ Convergence estimated for Neo Natal Mortality Rate (NNMR) across the 187 countries of the world, 1990-2008.

<table>
<thead>
<tr>
<th>Period</th>
<th>$\beta$ coefficient</th>
<th>P value</th>
<th>Adjusted $R^2$</th>
<th>Speed of convergence (in % per annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-2008</td>
<td>.04367 (.00685)</td>
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<td>-3.22</td>
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<tr>
<td>1990-2000</td>
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<td>.000</td>
<td>.15</td>
<td>-3.84</td>
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<tr>
<td>2000-2008</td>
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<td>.000</td>
<td>.15</td>
<td>-4.62</td>
</tr>
</tbody>
</table>

Note: n=187, df=186, Heteroscedasticity-consistant standard error are reported in parentheses.
Table 4. Convergence estimated for Post Natal Mortality Rate (PNMR) across the 187 countries of the world, 1990-2008.

<table>
<thead>
<tr>
<th>Period</th>
<th>$\beta$ coefficient</th>
<th>P value</th>
<th>Adjusted $R^2$</th>
<th>Speed of convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-2008</td>
<td>.02677 (.00700)</td>
<td>.000</td>
<td>.068</td>
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<tr>
<td>1990-2000</td>
<td>.02820 (.00853)</td>
<td>.000</td>
<td>.050</td>
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<tr>
<td>2000-2008</td>
<td>.04225 (.01152)</td>
<td>.000</td>
<td>.062</td>
<td>-3.64</td>
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</tbody>
</table>

Note: n=187, df=186, Heteroscedasticity-consistant standard error are reported in parentheses.

Table 5. Convergence estimated for Under 5 Mortality Rate (U5MR) across the 187 countries of the world, 1990-2008.

<table>
<thead>
<tr>
<th>Period</th>
<th>$\beta$ coefficient</th>
<th>P value</th>
<th>Adjusted $R^2$</th>
<th>Speed of convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-2008</td>
<td>.00828 (.00186)</td>
<td>.000</td>
<td>.0912</td>
<td>-0.77</td>
</tr>
<tr>
<td>1990-2000</td>
<td>.00968 (.00223)</td>
<td>.000</td>
<td>.087</td>
<td>-0.92</td>
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<tr>
<td>2000-2008</td>
<td>.011066 (.00270)</td>
<td>.000</td>
<td>.072</td>
<td>-1.06</td>
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</tbody>
</table>

Note: n=187, df =186, Heteroscedasticity-consistant standard error are reported in parentheses.


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Std. Deviation</td>
<td>169.60</td>
<td>180.46</td>
<td>3.92</td>
<td>2.92</td>
<td>5.87</td>
<td>4.66</td>
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<td>Variance</td>
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<td>11764.21</td>
<td>15.40</td>
<td>8.53</td>
<td>34.48</td>
<td>21.72</td>
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<td>162.42</td>
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<td>Skewness</td>
<td>-1.49</td>
<td>2.28</td>
<td>1.39</td>
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<td>1.02</td>
<td>2.01</td>
<td>1.26</td>
<td>1.78</td>
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<tr>
<td>Range</td>
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<td>20.00</td>
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<td>38.00</td>
<td>98.00</td>
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<tr>
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<td>-127.00</td>
<td>-4.00</td>
<td>-3.00</td>
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<td>-9.00</td>
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<td>-19.00</td>
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<tr>
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<td>664.00</td>
<td>569.00</td>
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<td>17.00</td>
<td>26.00</td>
<td>29.00</td>
<td>73.00</td>
<td>69.00</td>
</tr>
</tbody>
</table>