# Trends and Sub-national variation in Neonatal Mortality in India

**Nandita Saikia[1]**
**Chandra Shekhar[2]**
**Domantas Jasilionis[3]**
**Vladimir Shkolnikov[3]**

**Background:** Prior study showed that the mortality decline in India has been slowing down since the late nineties and that this largely depends in slowing down of the infant mortality reduction. The latter in turn largely depend on neonatal mortality, which constitutes 56 percent of all deaths. Earlier studies focused mainly the role of socio economic factors affecting infant and child mortality in India. This study analyzed the trends, regional patterns and disparities on neonatal mortality in India since early seventies. **Methods:** Decomposition of changes in NMR by time, state and type of residence (urban-rural) was done using Sample Registration System data. Inequality measures viz. range and population weighted Dispersion Measures of Mortality (DMM) were calculated to measure trend in regional inequality in NMR during the study period. **Results:** Analysis shows reduction in NMR is stagnant even in the era of health system reforms started since 2005. It also revealed presence of substantial regional and urban-rural disparity that present in NMR during 1970-2011. Although absolute inequality in NMR among regions has decreased over time, relative inequality appears to increase over time. **Conclusion:** Public health policies addressing under five mortality emphasis more on neonatal mortality with special reference to region of residence.

## Introduction

[1] Institute of Economic Growth, Delhi, email: nanditasts@gmail.com
[2] International Institute for Population Sciences, Mumbai
[3] Max Planck Institute for Demographic Research, Rostock

A significant attention has been paid by researchers analyzing infant and child mortality reduction in India during last four decades (Dommaraju et. al. 2008, Makepeace et. al. 2008, and UNICEF India 2012, Jain 1985; Arnold et al. 1998; Kravdal 2004; Mohanty 2011; Singh et al. 2011; Po and Subramanian 2011). The IMR was 130 per thousand live births before 1970s and begun to decline steadily after mid of the 1970s with the major reduction in the decades of 1980s and 1990s. The most recent estimate of IMR by Sample Registration System in India is 47per thousand live births in 2010 (Office of the Registrar General 2012). In spite, stagnation in the reduction in IMR or other mortality measures is observed since mid nineties (Claeson et al 2000; Saikia et al 2011). A cross country comparison of infant mortality rate using Demographic Health Survey data showed that over the 15 year period before 1992-93 National Family Health Survey, all measures of childhood mortality declined in India at rates slightly greater than the average for other low-income countries (Claeson et al 2000). However this decline has been slowed down since early nineties and child mortality reduction in India during 1990-2010 became lower than some south Asian countries including Bangladesh and Nepal (comparison of time series estimates of under five mortality rates available in Rajaratnam et al 2010). One of the important reasons behind this stagnation is recognized as increased role of neonatal mortality because of faster decline of post neonatal mortality (Figure 1). Trend of IMR and NMR in figure 1 showed that both indicators reduced minimum during 1991-2001 and afterwards reduction in IMR is much steeper than NMR. This is especially true after inauguration of National Rural Health Mission (NRHM) in 2005, a major health reforms focusing maternal and child health of 70 percent of total population. During post NRHM period (2006-2010), the reduction in IMR is 10 units whereas the same for NMR is only 4 units. Thus, India

experiences difficulties in addressing neonatal component of infant mortality effectively even the level of NMR is high.

[Figure 1 about here]

Out of 3 million neonatal deaths that occur each year globally, approximately 2.4 million occurs in developing countries (UN Inter-agency Group Report, 2012). In the last two decades since 1990, there is slower reduction in the neonatal mortality compared to under five mortality (Rammohan et al 2013; UN Inter-agency Group Report, 2012). In addition to this, neonatal mortality has become the principal contributor for infant and under five mortality. Globally, neonatal deaths contribute 41% to total under five death in 2008 (Oestergaard et al 2011). In India, the same figure in 2005-06 is about 52% (Rammohan et al 2013). India has the highest number of the neonatal deaths among all countries of the world amounting to 876,000 deaths in the year 2011 with neonatal mortality rate (NMR) of 31 per thousand live births. In the last four decades, there has been comparatively slow decline in the neonatal mortality in India compared to infant and under five mortality. As a result the relative contribution of the neonatal mortality to under five mortality has increasing continuously (SRS Reports, 1999 and 2010). This phenomenon may be attributed to the fact that there has been significant reduction in post neonatal and child mortality, but, the pace of reduction is relatively slow in the case of neonatal mortality. The high burden of the neonatal mortality is critical for achieving the desired MDG-4, related to infant and child mortality.

However, measuring the progress towards the achievement of MDG-4 at national level could be misleading (Sousa, Hill and Poz 2010) particularly in countries with great

inequalities. India, being the homeland of one billion plus population, experienced significant mortality inequality in all age groups by region, residence (rural-urban) and other socio-economic characteristics (Saikia et al 20011; Subramanian et al 2006). Thus examining neonatal mortality trend at sub-national level in India in past few decades is crucial for policy makers and health planners for effective decentralized and demand based policy.

**Earlier Studies on Neonatal Mortality on India**

As mentioned earlier, until recently both policy makers and researchers focused infant and child mortality in India (Jain, 1985; Gupta, 1990; Simmons et al., 1982; Narayana, 2008; Subramanian et al., 2006; Pradhan& Arokiasamy,2010; Joe, Mishra &Navaneetham, 2010; Behl, 2012; Bhattacharya & Chikwama, 2011) with no specific focus on neonatal mortality.

Most of earlier studies addressing neonatal mortality in India were focused on individual level neonatal death (Kumar 2013; Singh et al 2013; Arokiasamy and Gautam 2007). It has been brought out that along with bio-demographic factors health service utilization is also an important factor for the survival of the neonates (Rutstein, 2000). Literature suggest that use Tetanus Toxoid (TT) injections by pregnant mothers, keeping the baby warm ('kangaroo care'), place of post natal check up, household environment etc. are important determinants of neonatal mortality in India (Singh et al 2013; Singh et al 2012). It is also said that simple and cost effective service utilization like keeping the baby warm after pregnancy (kangaroo care) plays a positive role in child survival (Singh et al., 2012). Baby

care immediately after the birth is very important since 40% of all neonatal deaths occur on the first day of the life and 56% during the first three days (Rasaily, 2008).

Studies addressing causes of neonatal deaths are even scarcer. The primary causes of neonatal deaths in hospital born neonates are recognized as immaturity, Sepsis and birth asphyxia (Paul 1999). According to the million death study, a nationally representative survey conducted in 2001-2003, three most important causes for neonatal death in India are prematurity and low birth weight; neonatal infections, comprising neonatal pneumonia, neonatal sepsis and CNS infections; and birth asphyxia and birth trauma altogether accounting for 78% of neonatal deaths (Jha et al., 2010). Further, the study corroborates that there is cause specific variation in the neonatal and child mortality in India.

There is wide variation in the neonatal, infant and child deaths in various regions of India. In general, southern states have relatively lower neonatal, infant and child mortalities and the northern states. Empowered action group (EAG)[4] states, in particular, have very high neonatal, infant and child mortalities compared to other parts of India (Arokiasami al., 2008). The proportion of neonatal deaths to total child deaths is higher in higher income

states than in lower income states and; the proportion of total child deaths caused by the neonatal infections is higher in lower income states than in higher income states (Jha et al., 2010).

[4] In India, the eight socioeconomically backward states of Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Uttaranchal and Uttar Pradesh, referred to as the Empowered Action Group (EAG) states.

Nevertheless, none of earlier studies addressed the regional dynamics of neonatal mortality by regions in India with a special reference to rural-urban divide. This paper analyzed in detail the trend and differential of neonatal mortality at national and sub national level from 1971 to 2011.

## Data and Methods

### Data

To examine neonatal mortality rate (deaths of children in the first 28 days after the birth) for the period 1971-2009, we used Sample Registration System (SRS) data (Office of the Registrar General & Census Commissioner (India) 2009; Registrar General of India 2009, 2011).

SRS is based on the principles of the dual-record system involving both continuous registration in a nationally representative sample of villages and urban blocks, and a survey every six months for an independent count of events and to update demo- graphic particulars of the sample population. Events recorded in the two operations are matched. Unmatched and partially matched events are referred to the field for verification. It was started in 1969-1970 to generate reliable demographic indicators at national and state levels. The data quality issues of SRS are widely discussed (Saikia et al. 2011; Bhat 2002) and it is established that SRS estimates were likely to be accurate for child and adult ages under 60.

## Methods

Population-weighted Dispersion Measures of Mortality (DMM) and GINI coefficients were applied to estimate the trend in absolute inequality in neonatal. The DMM is defined as the average absolute inter-population difference in the mortality indicator (here it is neonatal/early mortality rate) across all pairs of populations, weighted by their sizes (here number of births). The decrease and increase in DMM show the decrease and increase in absolute inequality NMR among selected regions (for details see Moser et al. 2005). Since number of births for every year is not available directly from Census of India or SRS, those are estimated indirectly using crude death rates from SRS and total population from Census for the corresponding year.

For decomposing the changes in NMR, we used standard technique by Kitagawa (1955) given in appendix A.

## Results

### *Trends and Components of NMR Reduction*

Figure 2 shows the trend of neonatal mortality rates in India and bigger states during 1970 and 2011. At national level, neonatal mortality slightly increased until the year 1977; started declining sharply until 1993 and afterwards, the reduction slowed down significantly. The increase in NMR during 1971-77 might be due to increasing coverage of deaths in SRS.

[Figure 2 about here]

In absence of any other available data on neonatal deaths in early seventies, it becomes tricky to assess the completeness of deaths during neonate period. However a close look at regional pattern in NMR might strengthen our hypothesis. For example, in the year 1971, the state of Haryana has equal level of IMR with that of Kerala, one of the best performing states in terms of demographic indicators! This appeared really implausible when we observed the trend of Kerala and Haryana during this period. Kerala showed consistent decline over time and Haryana showed an increasing trend until 1997 and then started slowing down.

In addition to Haryana, some other states such as Tamil Nadu, Rajasthan, Andhra Pradesh showed increasing coverage in the early seventies. Thus most of the states, death registration situation has greatly improved by the 1980s. During same period, the trends of Karnataka, Maharashtra, Punjab, Odisha, Assam, and Uttar Pradesh appeared to be consistent. The peace of reduction of NMR varied significantly from region to region. The state of Uttar Pradesh showed almost stagnant NMR until 1983 and then experienced sharp decrease until 1996. NMR is almost stagnant in Punjab since mid nineties. In most recent years, only Tamil Nadu and Orissa achieved faster reduction in NMR compared to any other state. In the same period, the most populous states including Uttar Pradesh, Rajasthan, Madhya Pradesh and Odisha have higher neonatal mortality rate than the national average.

***Urban-rural Divide and Regional Disparities***

The trend of neonatal mortality rates in India and bigger states by type of residence (rural - urban) during 1971 and 2011 is showed in figure 3.

[Figure 3 about here]

The distinction between rural and urban NMR is clear and consistent over time. Throughout the period, rural NMR is higher than corresponding urban IMR for each region. In the year 1971 the gap between rural and urban NMR in India was of 35 (per 1000 live births) which has reduced to 17 (per 1000 live births) in the year 2010. The range of NMR among different states is wider in rural India compared to urban India. Since the majority of Indian population (approximately 69% of the population) is still mainly rural (Registrar General of India 2011), the rural pattern of neonatal mortality in figure 3 is analogous to the national pattern in figure 2.

There has been noteworthy change in the regional pattern of neonatal mortality rate in India in the last three decades. At the same time, the central Indian states of Uttar Pradesh and Madhya Pradesh have consistently been high neonatal mortality rate regions in the country. Unlike, the south-western state of Kerala has consistently been the lowest NMR in India in the last four decades (Figure 4).

[Figure 4 about here]

In the year 1981, there is clear cut regional divide with very high concentration of NMR in all central and eastern states along with western state Gujarat. Relative picture for southern states were satisfactory in 1981. By year 2011, the picture became more

complex. Regional disparities within southern states become prominent with Kerala falling in the lowest NMR category and Andhra Pradesh falling under the second highest NMR category. Similarly, eastern state West Bengal and northern state Punjab experienced lower NMR which is exceptional position in entire north and eastern region with very high level of NMR. The relative position of two most populous states viz. Uttar Pradesh and Madhya Pradesh remained same between 1981 and 2011. Interestingly, the newly created states Uttarakhand (erstwhile part of Uttar Pradesh) and Chhattisgarh (erstwhile part of Madhya Pradesh) experienced lower NMR than their parental states. The relative position of Orissa and Rajasthan has worsened from 1981 to 2011. On the other hand, Tamil Nadu and Maharashtra has shown tremendous progress in the reduction of NMR. Thus it is observed that reduction in the NMR in different states of India have been not uniform. Secondly, the number of high to very high NMR states has increased, particularly in the central, northern and eastern states of India.

[Table 1 about here]

Table 1 showed the ranking of states in descending order in NMR in 1981 and 2011. There is large reshuffle of states in India in the last three decades, if all states are arranged in ascending order of their NMR. However, the northern and eastern states have largely continued their position in the upper side of the ladder.

[Table 2 about here]

The trend in range and DMM during 1971-2011 is showed in table 2. The range between the best and the worst performing states significantly reduced from 67 to 39 during 1971-

2011 in rural India. The reduction in this range is much slower in case of urban India. The trend in DMM further substantiate the fact that over time, inter-state difference in neonatal mortality reduced faster way in rural India to urban India. The convergence in rural NMR among states occurred most during 1981-2001. Surprisingly there is slight increase in DMM in rural NMR during 2001-2011.

[Table 3 about here]

***Components of changes in NMR***

Decomposition analysis in NMR reduction by the effect of mortality and population shows that reduction in NMR is solely due to the reduction in mortality during 1981-2001 (twenty years) (table 3). In table 3, the negative value of any component indicated positive contribution in NMR reduction and vice-versa. For example, a mortality effect -29.8 for all states in 1981-2001 indicated mortality reduction of 29.8 units for all states during the reference period. The most populous state Uttar Pradesh contributed the highest fraction (about 30 percent of total reduction) in NMR reduction among all states. Next to Uttar Pradesh, West Bengal and Bihar contributed significantly in NMR reduction during this period. Some states with a very high level of NMR, say, Assam, Madhya Pradesh, Orissa and Rajasthan, the reduction in NMR is minimal. Although minimal, changing in Population composition played positive role in NMR increase in the most populous states Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh. In rest of the states, Population effect is negative or zero.

The total change in NMR in next ten years (2001-2010) was even negligible. During this period, changing population composition also contributed in the NMR reduction in a few states.

[Table 4 about here]

Table 4 shows decomposition of changes in NMR by rural and urban residence in selected states in 1981-2001 and 2001-2010. Clearly, reduction in NMR varied greatly from a maximum of 46 units in Uttar Pradesh to a minimum of 9.6 units in Karnataka in 19821-2001. Overall, mortality effect was more than population effect for both rural and urban India. For most states, mortality effect was stronger in rural area than the urban area. A complete contrast in population effect by rural urban residence is observed during this period. The population effect contributed in NMR reduction in rural area while it contributed positively in urban area.

Decomposition analysis of changes in NMR for by rural and urban residence for India and its states for the period 2001-2011 showed a similar picture in spite the magnitude of reduction fell significantly compared the earlier period.

**Summary and discussion**

Neonatal mortality rate in India reduced to more than half in past forty years. In spite the current figure is alarmingly high and is equivalent to ten times more than the NMR developed region in world.

Present study attempted to understand the trends and sub-national variation in neonatal mortality rate in India during 1971-2011. It focused regional dynamics of NMR change

with special reference to urban rural residence. It is found that the contribution of the neonatal mortality in infant mortality has been increasing continuously. Stagnation in neonatal mortality reduction and huge disparity across regions is major concern at present. In particular, neonatal mortality rate is higher in the most populous states situated at central, north and eastern states contributing huge absolute neonatal deaths overall. The pace of reduction in NMR did not corroborate with that of IMR. Post NRHM period (2006-2011), IMR reduction is much faster than NMR reduction. During past four decades, reduction in NMR varied significantly from region to region and from decade to decade. In most recent years, only the state of Tamil Nadu maintained a consistent steeper reduction in NMR. NMR in Karnataka is constant in most recent years rather at a high level.

On average, rural population is still at higher risk of experiencing NMR compared to urban population. It is worth to mention that there may be massive disparity in NMR within urban regions and hence some population sub-group might experience higher NMR than rural population. However we could address it due to lack of SRS information on it. Both the range and dispersion measure of mortality indicated that the regional convergence in NMR is much faster in rural areas compared to urban areas. It posed an important question: is this due to increasing number of low socio-economic sub-groups exposing higher deaths in urban slums?

Decomposition analysis further showed that the reduction in NMR is largely due to mortality effect. A few states played vital role in NMR reduction during the study period. Decomposition analysis by type of residence showed reduction in NMR is primary due to

reduction in NMR among rural areas. For both periods, population effect negatively contributed in NMR reduction in urban areas and vice versa.

Studies revealed that many of the neonatal deaths are because of the endogenous cause, that is, causes primarily influenced by the genetic make-up and circumstances arising before and during the birth (Arokiasami et al., 2008; Jha et al). Thus the perinatal and the neonatal survival require additional interventions and approaches since their causes of death are different from that of infant and child mortality (WHO, 2006, Jha et al., 2010). Until recently, half of all deliveries (52 percent) in India occurred at home in 2007-08 (Modugu et al 2012). With the conditional cash transfer schemes, popularly known as *Janani Suraksha Yojana (JSY)* and *Janani –Shishu Suraksha Karyakram (JSSK),* institutional delivery increased significantly to 78 percent in 2010-2011 (Ministry of Home and Family Welfare 2011).

Nevertheless wide regional variation in institutional delivery and quality of care during intrapartum/postpartum still remained questionable in India. For instance, out of total number of deliveries, only 58 percent of women received post partum check-up within 48 hours after delivery (Ministry of Home and Family Welfare 2011). Earlier study showed that prematurity and low birth weight is one major cause of neonatal deaths in India (Jha et al.). According GOI report, out of total reported births 20,472,026, 16 percent newborns was underweighted (less than 2.5 Kgs) (Ministry of Home and Family Welfare 2011). Similarly, studies revealed maternal anemia is closely linked with preterm birth and birth weight (Rasmussen 2001; Zhang et al 2009). Surprisingly, anemia prevalence among ever

married women of age 15-49 years increased significantly during 1998-99 to 2005-06 (Balarajan et al 2013).

Thus emphasizing on the number of institutional delivery might not be enough in India. Providing high-quality facility-based obstetric and neonatal care is equally important to improve neonatal survival in India. India probably can Add china' paper learn from her immediate neighbor China on combating neonatal mortality rate (Feng et 2011)

Since SRS data doesn't provide neonatal mortality rate by sex, we couldn't see sex differential in neonatal mortality in India.

## References


Arokiasami P. and Abhishek Gautum. 2008. "Neonatal Mortality in the empowered action group states of India: Trends and determinants" *Journal of Biosocial Science*, 40 : 183-201.

Kumar Chandan, Singh K. Prashant, Rai K. Rajesh and Singh Lucky. 2013. "Early Neonatal Mortality in India, 1990–2006," *Journal of Community Health (2013)*, 38: 120–130 DOI 10.1007/s10900-012-9590-8.

Corsi D. J, Bassani D. G, Kumar R, Awasthi S, Jotkar R, Kaur N, and Jha P. 2009. "Gender inequality and age-appropriate immunization coverage in India from 1992 to 2006," *Bio Med Central international Health and Human Rights*, 9 (Suppl. I): S3.

District Level Household and Facility Survey 2007-08. 2010. "District Level Household and Facility Survey 2007-08," *International Institute for Population Sciences (IIPS), Mumbai*, Ministry of Health and Family Welfare, Government of India.

Dommaraju P, Agadjanian V, and Yabiku S. 2008. "The pervasive and persistent influence of caste on child mortality in India," *Population Research and Policy Review*, 27(4): 477-495.

Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation. 2012. "Levels and Trends in Child Mortality Report 2012". http://www.unicef.org/videoaudio/PDFs/UNICEF_2012_child_mortality_for_web_0904.pdf

Feng X.L., Guo S, Hipgrave D, Zhu J, Zhang L, Song L, Yahng Q, Guo Y and Ronsmans C. 2011. "China's facility-based birth strategy and neonatal mortality: a population-based epidemiological study," *Lancet 2011*; published online Sept 16, 2011, DOI:10.1016/S0140-6736(11)61096-9.

Hanimi Reddya, Manas R. Pradhana, Rohini Ghosha, A G Khanb. 2012. "India's progress towards the Millennium Development Goals 4 and 5 on infant and maternal mortality," *WHO South-East Asia Journal of Public Health* 2012, 1(3): 279-289.

Jha P, and Shing L.K. 2010. "Causes of neonatal and child mortality in India: A nationally representative mortality survey," *Lancet* , 376: 1853-1860.

Kitagawa, E. 1955. "Components of a difference between two rates", *J Am Stat Assoc*, 50:1168–1194.

Lahiri S, Hazara A, and Abhishek S. 2011. "Sex-differentials in childhood mortality in Punjab and Haryana – Are they reality?" *Journal of Population Studies*, 43: 71-98.

Lin Shin-Jong. 2005. "The effect of economic instability on infant, neonatal, and postneonatal mortality rates: Evidence from Taiwan," *Social Science and Medicine*, 62: 2137-2150.

Mahy M. 2003. "Childhood mortality in the developing world," *Demographic Health, Comparative Report 4*, ORC Marco, Mariland, U.S..

Makepeace G, and Pal S. 2008. "Understanding the effect of siblings on child mortality: Evidence from India," *Journal of Population Economics*, 21 (4): 877-902.

Ministry of Health and Family Welfare . 2011. Family Welfare statistics in india – 2011: available at : https://nrhm-mis.nic.in/UI/FamilyWelfare2011/Complete%20BOOK/Complete%20BOOK.pdf accessed on 21st August 2013.

Modugu R.Hanimi, Kumar Manish, Kumar Ashok and Millett Christopher. 2012. "State and socio-demographic group variation in out-of-pocket expenditure, borrowings and Janani Suraksha Yojana (JSY) programme use for birth deliveries in India,"BioMed Central 5(12): 1048. doi: 10.1186/1471-2458-12-1048.

Oestergaard M.Z, Inoue M, Yoshida S, Mahanani W.R, Gore F.M, et al. 2011. "Neonatal Mortality Levels for 193 Countries in 2009 with Trends since 1990: A Systematic Analysis of Progress, Projections, and Priorities". *PLoS Med* 8(8): e1001080. doi:10.1371/journal.pmed.1001080.

Office of the Registrar General. 2012. "Sample Registration System Statistical Report, 2010," Repot No. 1 of 2012, *Office of the Registrar General of India*, Ministry of Home Affairs, Government of India, New Delhi.

Office of the Registrar General. 2009. "Sample Registration System Statistical Report, 2010," Repot No. 1 of 2009, *Office of the Registrar General of India*, Ministry of Home Affairs, Government of India, New Delhi.

Rasaily R. 2008. "Age profile of neonatal mortality," *Indian Pediatric*, Indian Council of Medical Research (ICMR), Young Infant Study Group, 45: 991-994. http://indianpediatrics.net/dec2008/991.pdf (accessed on 02-01-2013).

Rural Development Statistics 2002-03. "National Institute of Rural Development," *Annual Report, 2002-03*, Agriculture and Rural Development, New Delhi, Government of India.

Rural Development Statistics, (2010-11). "National Institute of Rural Development," *Annual Report, 2010-11*, Agriculture and Rural Development, New Delhi, Government of India.

Rutstein, S.O., 2000. "Factors associated with trends in infant and child mortality in developing countries during 1999s," *Bulletin of the World Health Organization (WHO)*, Geneva. 78(10).

Sample Registration System. 1999. "Compendium of India's fertility and mortality indicators 1971-97: Based on The Sample Registration System (SRS)" *Registrar General and Census Commission of India*, Ministry of Home Affairs, Government of India, New Delhi.

Sample Registration System. 1999. "Compendium of India's fertility and mortality indicators 1971-2007: Based on The Sample Registration System (SRS)" *Registrar General and Census Commission of India*, Ministry of Home Affairs, Government of India, New Delhi.

Sample Registration System. 2008. Sample Registration System Statistical Report, 2010; Repot No. 1 of 2008, *Office of the Registrar General of India*, Ministry of Home Affairs, Government of India, New Delhi.

Singh Abhishek, Yadav Awadesh and Singh Ashish. 2012. "Utilization of postnatal care for newborns and its association with neonatal mortality in India: An analytical approach," *Bio Medical Central, Pregnancy and Childbirth 2012*, 12: 33.

Singh Aditya, Kumar Abhishek and Kumar Amit. 2013. "Determinants of neonatal mortality in rural India, 2007–2008," *PubMed,* **PeerJ 1:e75**; **DOI 10.7717/peerj.75.**

Singh A, Pallikadavath S, Ogollah R, Stones W. 2012. "Maternal Tetanus Toxoid Vaccination and Neonatal Mortality in Rural North India," *PLoS ONE*, 7(11): e48891. doi:10.1371/journal.pone.0048891.

Sousa A, Hill K and DAl Poz R. Mario. 2010. "Sub-national assessment of inequality trends in neonatal and child mortality in Brazil," *International Journal for Equity in Health* 9:21
http://www.equityhealthj.com/content/9/1/21

Subramanian, S., S. Nandy, M. Irving, D. Gordon, H. Lambert, and G.D. Smith. 2006. "The mortality divide in India: The differential contributions of gender, caste, and standard of living across the life course." American Journal of Public Health 96(5):818-825.

Tracey J. Woodruff, Lyndsey A, Darrow and Jennifer D. Parker, 2008. "Air Pollution and Postneonatal Infant mortality in the United States, 1999-2002," *Environment and Health Perspective*, 116 (1): 110-105.

UNICEF India. 2012. "Infant and child mortality in India: Levels trends and Determinants," *National Institute of Medical Statistics (NIMS), Indian Council of Medical Research (ICMR), and UNICEF India Country Office*, New Delhi, India.

World Health Organization. 2006. "Neonatal and Perinatal Mortality: Country Region and Global Estimates; Department of making pregnancy safer," *World Health Organization (WHO)*, Geneva.

Zhang Q, Ananth C.V, Li Z and Smulian J.C. 2009. "Maternal anaemia and preterm birth: a prospective cohort study," *International Journal of Epidemiology*, 38(5):1380-1389. doi: 10.1093/ije/dyp243.

Figure 1: Trend in neonatal and infant mortality rates along with the share of neonatal mortality in infant mortality in India during 1971-2011

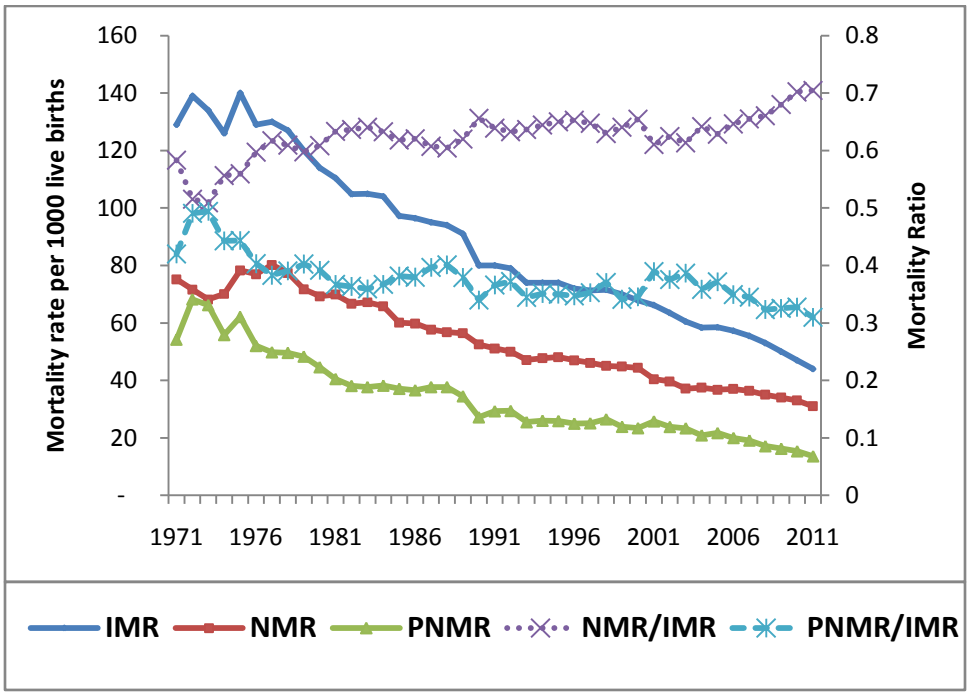


Figure 2: Trend of neonatal mortality rates in India and bigger states, 1971 and 2011

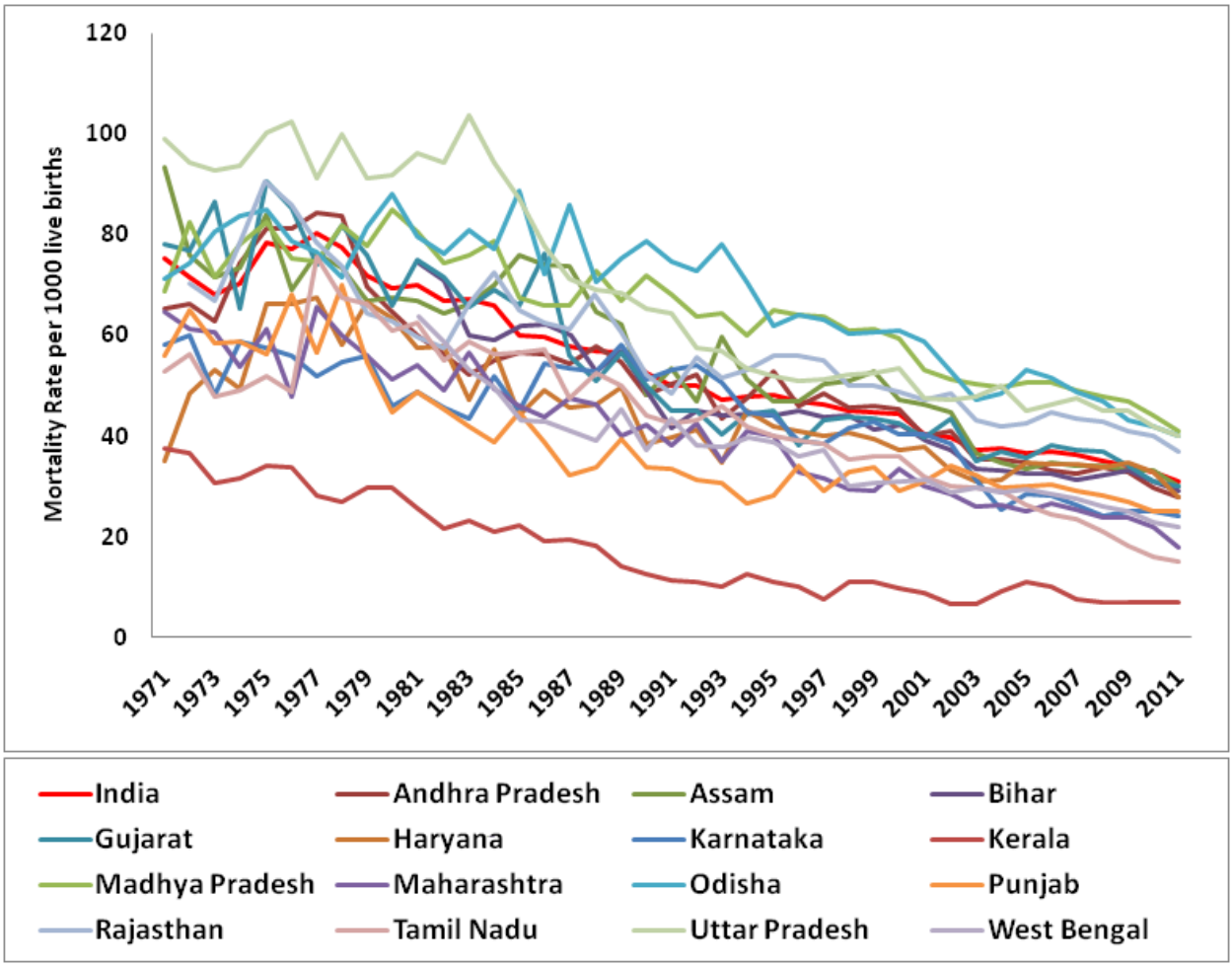


Figure 3.Trend of neonatal mortality rates in India and bigger states, 1971 and 2011

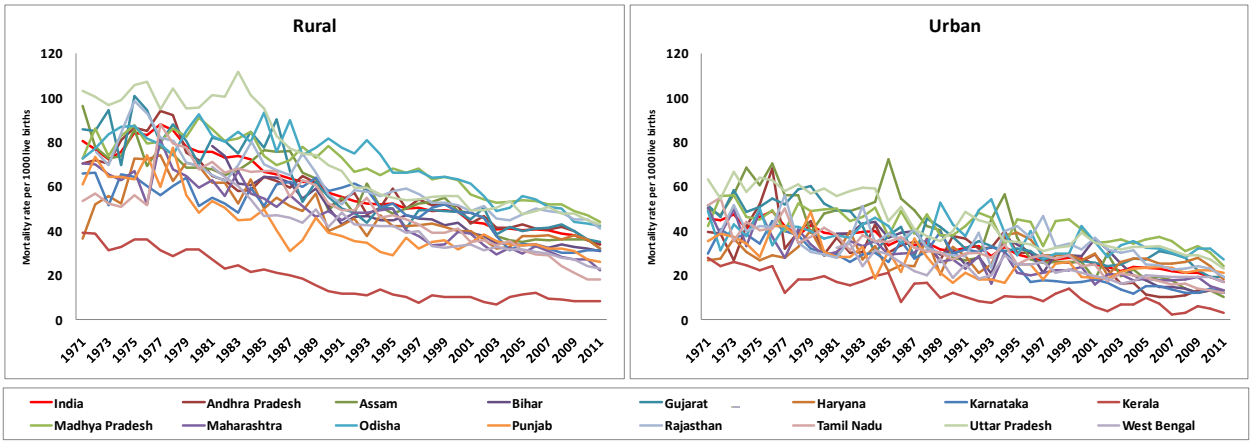

Figure 4: Maps of state level variations in NMR 1981 and 2011

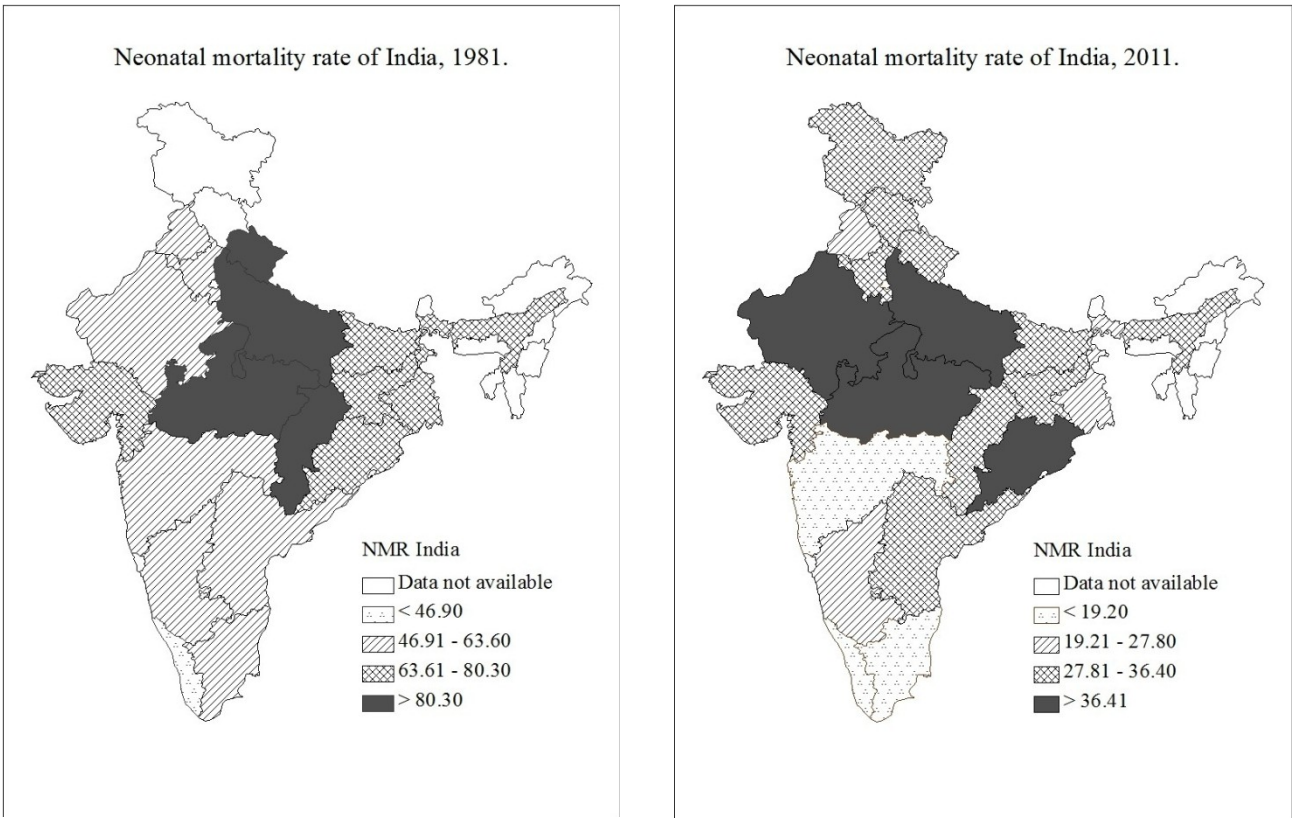

Table 1: Rank and live births of states in descending order of neonatal mortality rates in India in 1981 and 2011.

| States of India | 1981 | | States of India | 2011 | |
|---|---|---|---|---|---|
| | NMR | Live births | | NMR | Live births |
| Kerala | 25.7 | 651622 | Kerala | 6.8 | 507493 |
| Karnataka | 48.6 | 1050949 | Tamil Nadu | 15.2 | 1147009 |
| Punjab | 48.8 | 508707 | Maharashtra | 18.9 | 1876629 |
| Maharashtra | 53.6 | 1789316 | West Bengal | 21.9 | 1488968 |
| Haryana | 57.7 | 471653 | Punjab | 24.9 | 448809 |
| Rajasthan | 59.6 | 1271120 | Karnataka | 24.8 | 1149257 |
| Andhra Pradesh | 60.1 | 1697567 | Andhra Pradesh | 28.2 | 1481647 |
| Tamil Nadu | 62.6 | 1355424 | Haryana | 28.3 | 552697 |
| West Bengal | 63.9 | 1812089 | Bihar | 29.3 | 2875388 |
| Assam | 66.9 | 595353 | Gujarat | 29.8 | 1286171 |
| Bihar | 74.3 | 2045047 | Assam | 30.5 | 710659 |
| Gujarat | 74.9 | 1175967 | Rajasthan | 36.9 | 1797871 |
| Odisha | 79.7 | 872847 | Uttar Pradesh | 39.6 | 5548365 |
| Madhya Pradesh | 80.7 | 1435154 | Odisha | 40.9 | 843142 |
| Uttar Pradesh | 96.2 | 4163425 | Madhya Pradesh | 41.0 | 1952874 |
| **India** | **75.2** | **23164853** | **India** | **30.8** | **26382360** |

*Note: Live births are obtained by multiplying crude birth rate with total population.*

Table 2: Maximal and minimal values, Max-Min range, and Dispersion Measure of Mortality (DMM) for neonatal mortality rate in 1971-2011

| Years | Total | | | | | Urban | | | | | Rural | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Max-Min | DMM | Gini | Max | Min | Max-Min | DMM | Gini | Max. | Min. | Max-Min. | DMM | Gini |
| 1971 | 99 | 35 | 64 | 11 | 0.14 | 63 | 24 | 39 | 6 | 0.13 | 103 | 37 | 67 | 11 | 0.13 |
| 1981 | 96 | 26 | 71 | 10 | 0.14 | 56 | 17 | 39 | 6 | 0.15 | 101 | 27 | 74 | 9 | 0.12 |
| 1991 | 68 | 11 | 57 | 7 | 0.14 | 49 | 10 | 38 | 5 | 0.17 | 78 | 12 | 66 | 7 | 0.13 |
| 2001 | 59 | 9 | 50 | 5 | 0.12 | 37 | 6 | 31 | 5 | 0.19 | 61 | 9 | 52 | 5 | 0.11 |
| 2011 | 44 | 7 | 37 | 5 | 0.15 | 32 | 5 | 27 | 4 | 0.20 | 47 | 8 | 39 | 5 | 0.14 |

Table 3: Decomposition of changes in neonatal mortality rate by state in 1981-2001 and 2001-2011 (per 1000 live births)

| | 1981-2001 | | | 2001-2011 | | |
|---|---|---|---|---|---|---|
| States | Total Change | M effects | P effects | Total Change | M effects | P effects |
| Andhra Pradesh | -2.2 | -1.5 | -0.7 | -1.0 | -0.8 | -0.2 |
| Assam | -0.5 | -0.6 | 0.1 | -0.5 | -0.5 | 0.0 |
| Bihar | -3.0 | -3.7 | 0.7 | -0.8 | -1.2 | 0.4 |
| Gujarat | -2.1 | -1.9 | -0.2 | -0.5 | -0.5 | 0.0 |
| Harayana | -0.4 | -0.5 | 0.1 | -0.3 | -0.2 | 0.0 |
| Karnataka | -0.4 | -0.4 | 0.0 | -0.8 | -0.8 | 0.0 |
| Kerala | -0.6 | -0.5 | -0.1 | -0.1 | 0.0 | 0.0 |
| Madhya Pradesh | -1.3 | -2.0 | 0.7 | -0.8 | -1.0 | 0.2 |
| Maharashtra | -2.1 | -2.0 | 0.0 | -1.1 | -1.0 | -0.1 |
| Odisha | -1.2 | -0.8 | -0.4 | -0.7 | -0.7 | 0.0 |
| Punjab | -0.5 | -0.4 | -0.1 | -0.2 | -0.1 | -0.1 |
| Rajasthan | -0.1 | -0.8 | 0.7 | -0.7 | -0.8 | 0.1 |
| Tamil Nadu | -2.5 | -1.8 | -0.7 | -0.9 | -0.8 | 0.0 |
| Uttar Pradesh | -8.5 | -10.4 | 1.9 | -1.3 | -1.7 | 0.4 |
| West Bengal | -3.4 | -2.6 | -0.8 | -0.8 | -0.6 | -0.2 |
| All States | -28.7 | -29.8 | 1.1 | -10.4 | -10.8 | 0.3 |

Table 4: Decomposition of changes in NMR for by rural and urban residence for India and its states

A) 1981 to 2001

| States | Total Change | M effects | | P effects | | Total M effects | Total P effects |
|---|---|---|---|---|---|---|---|
| | | Urban | Rural | Urban | Rural | | |
| Andhra Pradesh | -19.4 | -1.7 | -16.6 | 1.8 | -2.9 | -18.3 | -1.1 |
| Assam | -20.7 | -2.6 | -17.8 | 0.4 | -0.7 | -20.4 | -0.3 |
| Bihar | -34.7 | -0.2 | -35.2 | -1.1 | 1.8 | -35.4 | 0.6 |
| Gujarat | -34.4 | -7.1 | -25.9 | 2.0 | -3.4 | -33.0 | -1.4 |
| Harayana | -18.7 | 0.0 | -17.2 | 2.1 | -3.6 | -17.2 | -1.5 |
| Karnataka | -8.9 | -3.2 | -4.9 | 0.7 | -1.5 | -8.0 | -0.8 |
| Kerala | -16.5 | -2.4 | -13.6 | 0.9 | -1.5 | -15.9 | -0.6 |
| Madhya Pradesh | -27.6 | -2.9 | -23.8 | 1.3 | -2.2 | -26.7 | -0.9 |
| Maharashtra | -23.9 | -5.3 | -15.6 | 2.6 | -5.6 | -20.8 | -3.0 |
| Odisha | -20.2 | -0.3 | -19.1 | 0.8 | -1.5 | -19.5 | -0.8 |
| Punjab | -17.2 | -2.7 | -13.6 | 1.0 | -1.8 | -16.3 | -0.8 |
| Rajasthan | -12.1 | 1.6 | -13.4 | 0.4 | -0.6 | -11.8 | -0.3 |
| Tamil Nadu | -31.0 | -4.6 | -23.6 | 4.1 | -6.8 | -28.2 | -2.8 |
| Uttar Pradesh | -47.6 | -3.3 | -43.4 | 1.4 | -2.4 | -46.7 | -0.9 |
| West Bengal | -31.8 | -2.3 | -28.9 | 0.7 | -1.4 | -31.2 | -0.7 |
| All States | -28.8 | -2.8 | -25.0 | 1.2 | -2.3 | -27.7 | -1.1 |

Table 4: Decomposition of changes in NMR for by rural and urban residence for India and its states

B) 2001 to 2011

| | Total Change | M effects | | P effects | | Total M effects | Total P effects |
|---|---|---|---|---|---|---|---|
| | | Urban | Rural | Urban | Rural | | |
| Andhra Pradesh | -12.5 | -4.8 | -6.6 | 1.3 | -2.4 | -11.4 | -1.1 |
| Assam | -15.8 | -0.8 | -14.9 | 0.1 | -0.2 | -15.6 | -0.2 |
| Bihar | -9.8 | -2.0 | -7.6 | 0.3 | -0.4 | -9.7 | -0.1 |
| Gujarat | -9.9 | -2.3 | -6.6 | 1.3 | -2.3 | -8.9 | -1.0 |
| Haryana | -9.6 | -3.3 | -5.5 | 1.5 | -2.2 | -8.8 | -0.7 |
| Karnataka | -15.1 | -1.9 | -11.6 | 1.0 | -2.6 | -13.5 | -1.6 |
| Kerala | -3.1 | -0.9 | -1.2 | 0.9 | -1.9 | -2.1 | -1.0 |
| Madhya Pradesh | -12.2 | -2.2 | -9.8 | 0.2 | -0.4 | -12.0 | -0.2 |
| Maharashtra | -11.1 | -1.2 | -9.6 | 0.2 | -0.5 | -10.8 | -0.3 |
| Odisha | -17.9 | -1.0 | -16.8 | 0.0 | -0.1 | -17.9 | 0.0 |
| Punjab | -5.5 | 0.8 | -5.7 | 1.1 | -1.7 | -4.9 | -0.6 |
| Rajasthan | -10.2 | -3.6 | -6.2 | 0.7 | -1.1 | -9.8 | -0.4 |
| Tamil Nadu | -16.7 | -7.0 | -7.7 | 4.5 | -6.5 | -14.7 | -1.9 |
| Uttar Pradesh | -7.8 | -2.2 | -5.3 | 0.4 | -0.7 | -7.5 | -0.3 |
| West Bengal | -9.4 | -0.5 | -8.5 | 0.7 | -1.1 | -9.0 | -0.4 |
| All States | -10.3 | -1.9 | -7.8 | 0.7 | -1.2 | -9.7 | -0.6 |

**Appendix A**

The method for decomposing the differences between two NMR into population and mortality effect is given in equation (1) (Kitagawa 1955)

$$NMR(t_2)-NMR(t_1)=\left[\left(P(t_2)-P(t_1)\right)\cdot\frac{1}{2}\cdot\left(NMR(t_2)+NMR(t_1)\right)\right]+\left[\left(NMR(t_2)-NMR(t_1)\right)\cdot\frac{1}{2}\cdot\left(P(t_2)+P(t_1)\right)\right] \quad \text{----------(1)}$$

where $t_2$ and $t_1$ are two calendar periods; $P(t_i)$, $i=1, 2$ is percent share of live births to the total births, $NMR(t_i)$, $i=1,2$ is neonatal mortality rate at calendar period $t_i$. The first component measures the effect of changes in population composition given average rates of NMR in time $t_1$ & $t_2$. *Similarly* the second component measures the effect of changes in NMR given average population composition in time $t_1$ & $t_2$.

Similarly the method for decomposing the differences between two NMR into population and mortality effect by urban and rural population is given in equation (2).

$$NMR(t_2)-NMR(t_1)=\left[\left(P^u(t_2)-P^u(t_1)\right)\cdot\frac{1}{2}\cdot\left(NMR^u(t_2)+NMR^u(t_1)\right)\right]+\left[\left(P^r(t_2)-P^r(t_1)\right)\cdot\frac{1}{2}\cdot\left(NMR^r(t_2)+NMR^r(t_1)\right)\right]$$
$$+\left[\left(NMR^u(t_2)-NMR^u(t_1)\right)\cdot\frac{1}{2}\cdot\left(P^u(t_2)+P^u(t_1)\right)\right]+\left[\left(NMR^r(t_2)-NMR^r(t_1)\right)\cdot\frac{1}{2}\cdot\left(P^r(t_2)+P^r(t_1)\right)\right]$$
----------(2)

where $t_2$ and $t_1$ are two calendar periods; $P^u(t_i)$, $i=1, 2$ is percent share of live births to the total births in urban area, $P^r(t_i)$, $i=1, 2$ is percent share of live births to the total births in rural area, $NMR^u(t_i)$, $i=1,2$ is neonatal mortality rate at calendar period $t_i$ in urban area, $NMR^r(t_i)$, $i=1,2$ is neonatal mortality rate at calendar period $t_i$ in rural area.