Using Markov Chain To Predict The Probability Of Rural And Urban Child Mortality Rates Reduction In Ghana

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Abstract: Child mortality reflects a country's level of socio-economic development and quality of life. In this paper, Markov chain is used to predict the probability of rural and urban child mortality rate reduction in Ghana. The probabilities of whether the rural and urban mortality rates will increase was obtained from the current data where the probability of rates increasing is less than 20%. After applying Markov, it was realized that the current rates are not likely to change, that is the reduction rates will remain the same if proactive measures are not put in place to reduce the CMR drastically. It is therefore recommended to the government to put in more effort in ensuring that the rates go down. This is because if we depend on the current rates we will not be able to achieve the Millennium Development Goal (MDG) 4 by 2015.

Keyword: child mortality rate, Ghana mortality rates, Markov chain, mortality rate prediction, rural mortality, urban mortality

1 INTRODUCTION

CHILD mortality, also known as under-5 mortality, refers to the death of infants and children under the age of five. In 2011, 6.9 million children under five died, down from 7.6 million in 2010, 8.1 million in 2009, and 12.4 million in 1990. About half of child deaths occur in Sub-Saharan Africa. Reduction of child mortality is the fourth of the United Nations' Millennium Development Goals. Child Mortality Rate is the highest in low-income countries, such as most countries in Sub-Saharan Africa. A child's death is emotionally and physically painful for the parents and the country at large. Many deaths in the developing countries go unnoticed since many poor families do not see the need to register their babies in the government registry The fourth Millennium Development Goal (MDG 4) aims to reduce the 1990 mortality rate among under-five children by two thirds. Child mortality is also closely linked to MDG 5- to improve maternal health. Since more than one third of all child deaths occur within the first month of life, providing skilled care to mothers during pregnancy, as well as during and after birth, greatly contributes to child survival. Millennium Development Goals adopted by the United Nations in 2000 aim to decrease child deaths worldwide by 2015.

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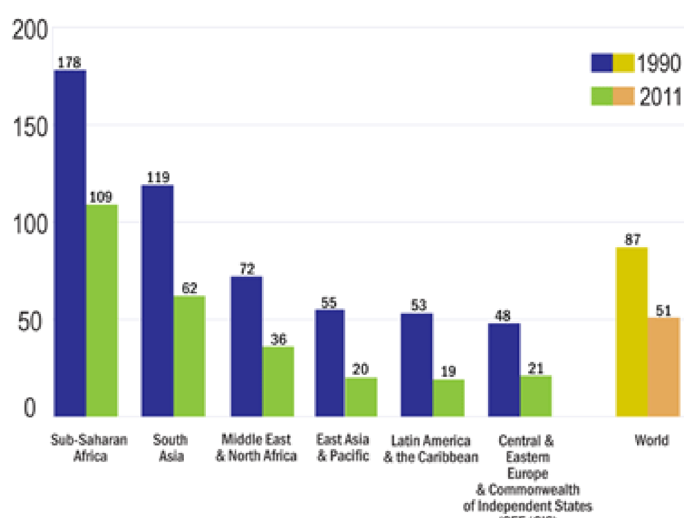
1.1 Background of the study

Despite population growth, the number of deaths in children under five worldwide declined from nearly 12 million in 1990 to 6.9 million in 2011. The proportion of under-five deaths that occur within the first month of life (the neonatal period) has increased from 36% in 1990 to about 43% in 2011. The rate of decline in under five mortality has accelerated from 1.8% a year over 1990-2000 to 3.2% a year over 2000-2011. The highest levels of under-five mortality continue to be found in Sub-Saharan Africa, where 1 in 9 children die before the age of five. Under-five deaths are increasingly concentrated in Sub-Saharan Africa and South Asia, while the share of the rest of the world dropped from 31% in 1990 to 17% in 2011. But many more lives can be saved. While the global number of under-five deaths has dropped since 1990, this still translates into nearly 19,000 children dying every day in 2011. Almost two thirds of all under-five deaths are the result of infectious diseases and conditions, such as pneumonia, diarrhoea, malaria, measles and AIDS – deaths which could have been prevented.

Figure 1; world under five mortality rate, 1990-2011, by UNICEF region

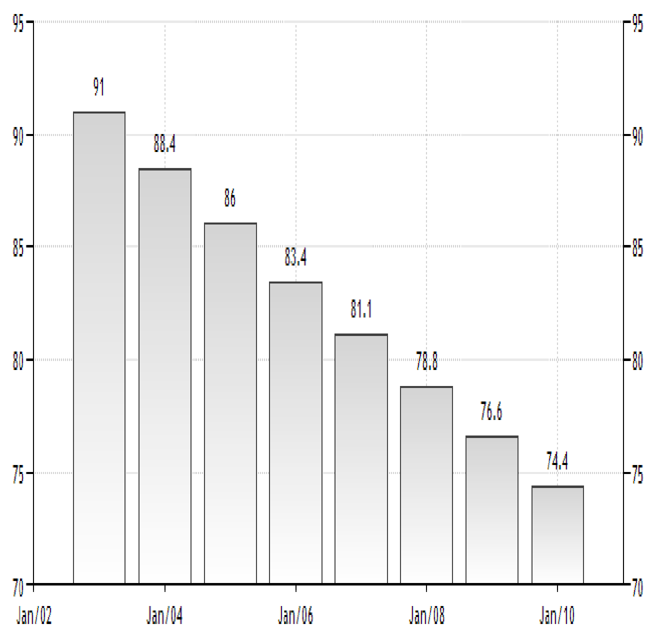


From the above figure, all regions have experienced marked decline in under-five mortality rate since 1990.The highest rates of under-five mortality continue to be in sub-Saharan Africa, where 1 child in 9 dies before age five.

1.2 Child mortality in Ghana

According to [8], Ghana however has made phenomenal progress over the years in immunization coverage, from a national coverage of four per cent in 1985 to 90 per cent in 2012. Furthermore, poverty usually limits access to health care and restricts appropriate and balanced diets. Inequities in exposure and resistance add up to inequities in coverage of available preventive interventions, access to an appropriate health provider, and care, making poor children more likely to become sick than the better-off children [7]. According to [9], most child deaths (and 70% in developing countries) which include Ghana. The Mortality rate; under-5 (per 1;000) in Ghana was last reported at 74.40 in 2010, according to a World Bank report published in 2012. Under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching age five, if subject to current age-specific mortality rates. Below is a historical data chart for Mortality rate; under-5 (per 1;000) in Ghana.

Figure 2; under five mortality rate in Ghana, 2002-2010



Ghana is expected to reduce its current child mortality rate to about 40 per 1000 life birth in 2015 we should reach 40. But our average annual reduction rate is about 2.5%

Table 1; infant and child mortality rate in Ghana

Region	Infant Mortality Rate					Under Five Mortality Rate				
	1988	1993	1998	2003	2008	1988	1993	1998	2003	2008
Western	76.9	76.3	68.0	66.0	51.0	151.2	131.8	109.7	109.0	65.0
Central	138.3	71.6	83.8	50.0	73.0	208.2	128.0	142.1	90.0	108.0
Greater Accra	57.7	58.4	41.4	45.0	36.0	103.8	100.2	62.0	75.0	50.0
Volta	73.5	77.8	53.8	75.0	37.0	132.7	116.4	98.0	113.0	50.0
Eastern	70.1	55.9	50.2	64.0	53.0	138.1	93.2	89.1	95.0	81.0
Ashanti	69.8	65.2	41.9	80.0	54.0	144.2	97.6	78.2	116.0	80.0
Brong Ahafo	65.0	48.7	77.3	58.0	37.0	122.6	94.6	128.7	91.0	76.0
Northern	103.1	113.7	70.1	69.0	70.0	221.8	237.0	171.3	154.0	137.0
Upper East	103.1	105.0	81.5	33.0	46.0	221.8	180.1	155.3	79.0	78.0
Upper West	103.1	84.5	70.6	105.0	97.0	221.8	187.7	155.6	208.0	142.0
National	**77**	**66**	**57**	**64**	**50**	**155**	**119**	**108**	**111**	**80**
Rural	86.8	82.2	67.5	70.0	56.0	162.5	149.2	122.0	118.0	90.0
Urban	66.9	54.9	42.6	55.0	49.0	131.1	89.9	76.8	93.0	75.0

Source: DHS 1988, 1993, 1998, 2003, 2008

1.3 Objective

The objective of this study is to adopt Markov model for the prediction of the probabilities of under-five child mortality status in rural and urban annual mortality rate in Ghana. It is also to test whether we can depend on current rates to be able to achieve the Millennium Development Goal (MDG) 4 by 2015.

2 LITERATURE REVIEW

[3] developed A "Markov cycle tree" cohort model was in Excel with Visual Basic to compare the number of deaths from pneumonia in children aged 1 to 59 months expected under three scenarios:

1. No curative services available,
2. Curative services provided by a highly-skilled but intermittent mobile clinic, and
3. Curative services provided by a low-skilled community health post.

Parameter values were informed by literature and expert interviews. Probabilistic sensitivity analyses were conducted for several plausible scenarios. In [4] model, reduction in child mortality may either rise or lower fertility. When the level of child mortality is high, reduction in it is likely to raise both fertility and survival enhancing expenditures on children, because it lowers the price of a surviving child. [1] Made an attempt to investigate the interaction between child mortality and poverty in Pakistan. The analysis was relied on the Pakistan Socio-economic Survey conducted during April to July 1999. The study applied multiple classification analysis that requires dependent variable not to be badly skewed. The study found that mother's work participation, household crowding, unadjusted housing conditions and malnutrition have significant negative impact on the livelihood of a child. A decision analytic model was developed according to the stages recommended by [2] by specifying the decision problem and boundaries of analysis, structuring the decision model, identifying appropriate evidence, and dealing with uncertainty and heterogeneity. [6] Did a study who's analysis was based on micro data from the 2005 Demographic and health Survey. Bayesian Semi Parametric Probit Model for discrete time survival data and Markov-Chain Monte Carlo methods (MCMC), revealed several variables, including the age of the mother and the breast feeding duration whose effects exhibited distinct age-dependencies. In the case of breast feeding, age dependency was intimately linked with the reasons for stopping breast feeding

3 METHODOLOGY

Markov Chain Definition A stochastic process $\{ X_n \}$ is called a Markov chain if

$\Pr\{ X_{n+1} = j \mid X_0 = k_0, \ldots, X_{n-1} = k_{n-1}, X_n = i \}$

$= \Pr\{ X_{n+1} = j \mid X_n = i \}$ ← transition probabilities

for every $i, j, k_0, \ldots, k_{n-1}$ and for every n.

Discrete time means $n \in N = \{ 0, 1, 2, \ldots \}$.

The future behavior of the system depends only on the current state i and not on any of the previous states.

$\Pr\{ X_{n+1} = j \mid X_n = i \} = \Pr\{ X_1 = j \mid X_0 = i \}$ for all n

(They don't change over time)

We will only consider stationary Markov chains. The one-step transition matrix for a Markov chain with states $\boldsymbol{S} = \{ 0, 1, 2 \}$ is

$$P=\begin{bmatrix} P_{00} & P_{01} & P_{02} \\ P_{10} & P_{11} & P_{12} \\ P_{20} & P_{21} & P_{22} \end{bmatrix}$$

where $p_{ij} = \Pr\{ X_1 = j \mid X_0 = i \}$

3.1 Data presentation and analysis

The table below was extracted from table 1

Area	1988	1993	1998	2003	2008
Rural	162.5	149.2	122.0	118.0	90.0
Urban	131.1	89.9	76.8	93.0	75.0

Assumptions from the above table The probability that the rural mortality rate will increase is 0 as over the years there has been a decrease in the rates. The probability that the urban mortality rate will rise is about 0.2 since it was one out of the five years that went up(that was 2003) It could therefore be assumed that the probability that both rates will increase in a particular year is very small. Therefore the following area (Rural and urban) prediction can be used;

- Two areas (rural and urban) are used to determine national child mortality rate.
- When both are used in a year, there is a 10% chance that one will go up and a 5% chance that both will go up.
- If only one area will go down at the beginning of the year, there is a 10% chance that it will go up by the end of the year.
- If neither will go down at the beginning of the year, measures are put in place to let it go down that is more effort are put into ensuring that it go down by the end of the year.
- Areas that go up during the year are monitored to make sure it is minimize by the close of the year.
- The system is observed after the measures have been put in place to ensure that it does not rise by the end of the year.

States for rural and urban area

Table2; states for rural and urban areas

Index	State	State definitions
0	**s** = (0)	Non went up. The year started with all areas having reduced mortality rate as compared with the previous year.
1	**s = (1)**	One went up. The year started with one area going up.
2	**s = (2)**	Both areas went down.

Events and Probabilities for rural and urban areas

Table 3; probabilities for each state

Index	Current state	Events	Probability	Next state
0	$s^0 = (0)$	Neither areas went up	0.85	**s'** = (0)
		One area went up	0.10	**s' = (1)**
		Both areas went up	0.05	**s' = (2)**
1	**$s^1 = (1)$**	Remaining area does not go up and the other went down	0.9	**s' = (0)**
		Remaining area goes up and the other area goes down.	0.1	**s' = (1)**
2	**$S^2 = (2)$**	Both areas went down when measures are put in place to ensure they all go down.	1	**s' = (0)**

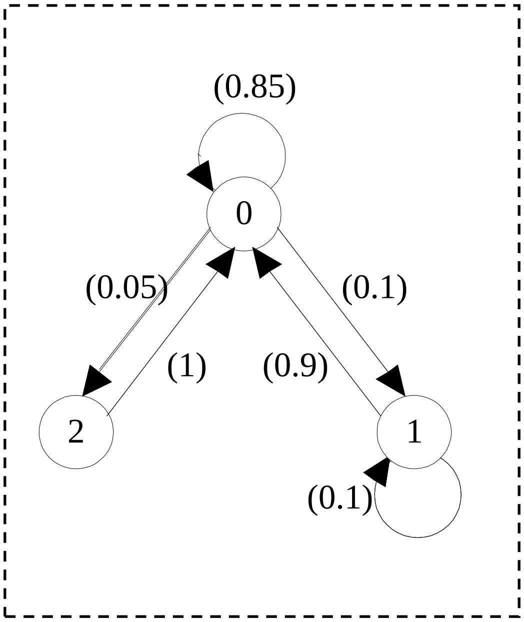
<u>State-Transition Matrix and Network for CMR in Ghana</u>

The events associated with a Markov chain can be described by the $m \times m$ matrix: $\mathbf{P} = (p_{ij})$.

For rural and urban areas, we have: $P=\begin{bmatrix} 0.85 & 0.10 & 0.05 \\ 0.9 & 0.1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$

State-Transition Network

- Node for each state
- Arc from node i to node j if $p_{ij} > 0$.



Multi-step (n-step) Transitions

The **P** matrix is for one step: n to $n + 1$.

states: $\mathbf{s}^0 = 0$ (non went up), $\mathbf{s}^1 = 1$ (one went up) $s^2=2$ (both went up)

Transition matrix: $P=\begin{bmatrix} 0.85 & 0.10 & 0.05 \\ 0.9 & 0.1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$

Interpretation: $p_{01} = 0.1$, is conditional probability of mortality rate in one area going up next year given that non went up this year.

<u>Two-step Transition Probabilities</u>

Let p_{ij} be probability of going from i to j in two transitions. In matrix form, $\mathbf{P}^{(2)} = \mathbf{P} \times \mathbf{P}$, so for IRS example we have

$$P^2=\begin{bmatrix} 0.85 & 0.10 & 0.05 \\ 0.9 & 0.1 & 0 \\ 1 & 0 & 0 \end{bmatrix} \times \begin{bmatrix} 0.85 & 0.10 & 0.05 \\ 0.9 & 0.1 & 0 \\ 1 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0.8625 & 0.095 & 0.0425 \\ 0.855 & 0.1 & 0.045 \\ 0.85 & 0.1 & 0.05 \end{bmatrix}$$

The resultant matrix indicates, for example, that the probability of rates not increasing 2 years from now given that the current year there was no increase is $p_{00} = 0.8625$

<u>*n*-Step Transition Matrix for CMR</u>

Table 4; results of n-step transition matrix

Time, *n*	Transition matrix, $\mathbf{P}^{(n)}$
1	$\begin{bmatrix} 0.85 & 0.10 & 0.05 \\ 0.9 & 0.1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$
2	$\begin{bmatrix} 0.8625 & 0.095 & 0.0425 \\ 0.855 & 0.1 & 0.045 \\ 0.85 & 0.1 & 0.05 \end{bmatrix}$
3	$\begin{bmatrix} 0.861125 & 0.09575 & 0.043125 \\ 0.86175 & 0.0955 & 0.04275 \\ 0.8625 & 0.095 & 0.0425 \end{bmatrix}$
4	$\begin{bmatrix} 0.861256 & 0.095688 & 0.043056 \\ 0.861188 & 0.095725 & 0.043088 \\ 0.861125 & 0.09575 & 0.043125 \end{bmatrix}$
5	$\begin{bmatrix} 0.861243 & 0.095694 & 0.043063 \\ 0.861249 & 0.095691 & 0.043059 \\ 0.861256 & 0.095688 & 0.043056 \end{bmatrix}$

4 INTERPRETATION OF RESULTS AND CONCLUSION

For $P^{(2)}$ that is in two years time when we are to reach the MDG as country this is the probabilities we to expect given the current child mortality rates.

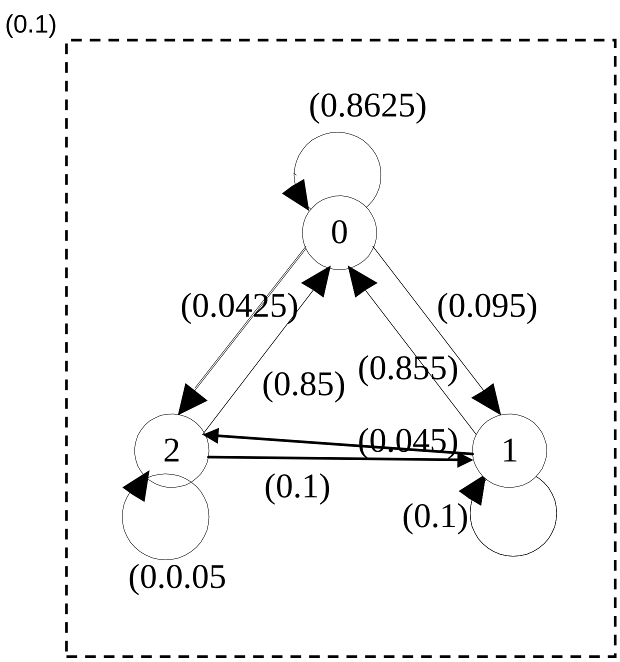


Table5: analysis of results

Index	Current state	Events	Probability	Next state
0	$\mathbf{s}^0 = (0)$	Neither areas went up	0.8625	**s'** = (0)
		One area went up	0.095	**s' = (1)**
		Both areas went up	0.0425	**s' = (2)**
1	$\mathbf{s}^1 = \mathbf{(1)}$	Remaining area does not go up and the other went down	0.855	**s' = (0)**
		Remaining area goes up and the other area goes down.	0.1	**s' = (1)**
		Remaining area goes up and the other area goes up.	0.045	**s' = (2)**
2	$\mathbf{S}^2 = \mathbf{(2)}$	Both areas went down when measures are put in place to ensure they all go down.	0.85	**s' = (0)**
		One area will go up	0.1	**s' = (1)**
		Both areas will go up	0.05	**s' = (2)**

From the above results it could be said that Ghana is still not safe since it still have the potential of child mortality rate increasing in years ahead. That is for example if we take 2 years ($P^{(2)}$) to come which is the MDG we still have 86%(P_{00}) chance of not increasing the current rates. We have a 10% chance of one area going up. This means we are still not certain or 100% sure whether the rates will be reduced or not. Even if our rates will not increase it means as for reaching the target is out of the question. Since we are still battling with the reduction rates. There is therefore the need for governments and stakeholders to put in more efforts in making sure that we are able to get 100% certainty that our mortality rates will not increase in the years ahead and then battle with how to reduce the mortality rates drastically in order to reach our target of Millennium Development Goals on child mortality.

5 RECOMMENDATIONS

The government needs to educate citizen more on how to curb this mortality because most of the causes of death in under-five are preventable. So if governments are committed in educating their citizens on the preventive measures to take or to rush children to hospital for early treatment this could help reduce the rate drastically. They should also see to it that the long queues for children under-five at the hospitals is also reduce since this is what prevents most people from sending their children to hospitals. Also families especially mothers should be educated on the effects of under-five mortality on the family, community and country at large. They should treat under-five death cases as criminal cases if the fault is from the parent, to deter others from delaying when they see that their children are indisposed. Again there should be free health care for all children under-five as most parents cannot afford the basic health care for their wards. Citizens should be made to know that they are those who are not helping in the MDG. When you see other countries recording 90% reduction rate and Ghana recording less than 50% then citizens should be alarmed and therefore see to it that their behavioral patterns will helps in the reduction. Researchers should research more into the reasons why Ghana is not reaching about 50% reduction rate and find solutions to the problem for us to use the research findings. Children under-five are dying every year, down from over 12 million in 1990. Most of these children are dying in developing countries from preventable causes for which there are known and cost-effective interventions. Unless efforts are increased there will be little hope of averting the additional 5.4 million child deaths per year, or a reduction of two-thirds, needed to achieve Millennium Development Goal (MDG) 4 by 2015.

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