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Original Research Article

CHILD MORTALITY RATES IN ASIA

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Abstract: - 5.9 million Children under the age of 5 died in 2015. More than half of these early child deaths are due to conditions that could be prevented or treated with access to simple, affordable interventions. Leading causes of death in under-5 children are preterm birth complications, pneumonia, birth asphyxia, diarrhoea and malaria. About 45% of all child deaths are linked to malnutrition.The main purpose of this paper is to analyze the variation in averageunder-5 child mortality rates among the countries of Asia on the basis of available statistical data for the period 1995-2013 and shed some light for under-5 child mortality rate management. Using the linear discriminant function analysis technique, the study has shown that significant discriminating factors responsible for the variation in child mortality rate are GDP per capita, access to the improved water and sanitation, number of physicians, and number of nurses and midwifery persons. Multinomial logistic regression shows the variables like immunization rate, general government health expenditure , number of physicians per 10,000 population, number of hospital beds per 10,000 population, access to improved water and sanitation are significant negatively for categories 2 and 3 indicating that increasing the value of these predictors is associated with decreased odds of achieving lower under-5 child mortality.

Introduction: A child's risk of dying is highest in the neonatal period, the first 28 days of life. Safe childbirth and effective neonatal care are essential to prevent these deaths. 45% of child deaths under the age of 5 take place during the neonatal period. Preterm birth, intrapartum-related complications (birth asphyxia or lack of breathing at birth), and infections cause most neonatal deaths. From the end of the neonatal period and through under-5 first 5 years of life, the main causes of death are pneumonia, diarrhoea and malaria. Malnutrition is the underlying contributing factor in about 45% of all child deaths, making children more vulnerable to severe diseases. Overall, substantial progress has been made towards achieving Millennium Development Goal (MDG) 4. Since 1990 the global under-5

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mortality rate has dropped from 91 deaths per 1000 live births in 1990 to 43 in 2015. But the rate of this reduction in under-5 mortality was insufficient to reach the MDG target of a two-thirds reduction of 1990 mortality levels by the year 2015 (WHO, 2016) [1].

Several studies [2, 3] have shown the importance of role of national income and other development features in reducing the child mortality rate under 5s. The main purpose of this paper is to analyze the variation in average under-5 child mortality rate among the countries of Asia on the basis of available statistical data for the period 1995-2013. The average under-5 child mortality rates have been classified into three categories. The study makes an attempt to find the factors responsible for the variation in average under-5 child mortality rates. Higher the value of predictors like GDP per capita, immunization rate, total health expenditure as % of GDP, general government health expenditure as % of total government expenditure, number of physicians per 10,000 population, number of nursing and midwifery persons per 10,000 population and number of hospital beds per 10,000 population, access to improved water and sanitation, lower the under-5 child mortality rate. Similarly, lower the values of rate of undernourishment, private health expenditure as % of total health expenditure and out-of pocket health expenditure as % of total private health expenditure, lower the rate of under-5 child mortality.

Materials and Methods: The main source of data is from UN ESCAP statistics. Following variables are used in our analysis.

1) Under.5.mort.rate: Under-five mortality rate [Deaths per 1,000 live births],
2) DPT3: immunization rate for children 1 year of age [% of 1-year-olds] - The percentage of 1-year-olds who have received three doses of the combined diphtheria, tetanus toxoid and pertussis vaccine in a given year,
3) GDP_PCI: GDP per capita in US dollars at 2005 prices,
4) Tot.h.exp.percent: Total health expenditure [% of GDP],
5) Tot.h.exp.PC$: Total health expenditure [Per capita PPP dollars] in US dollars at 2005 prices,
6) Gen.Govt.h.exp.Pc$: General government health expenditure [Per capita PPP dollars] in US dollars at 2005 prices,
7) Gen.gov.h.exp.percent: General government health expenditure [% of government expenditure],
8) Pri.h.exp.percent: Private health expenditure [% of total health expenditure],
9) Out of pocket h.exp.percent: Out-of-pocket health expenditure [% of private health expenditure]-The direct outlay of households, including gratuities and payments in kind, made to health practitioners and suppliers of pharmaceuticals, therapeutic appliances and other goods and services, whose primary intent is to contribute to the restoration or to the enhancement of the health status of individuals or population groups,
10) No. of. Physicians: Number of physicians [Per 10,000 population],
11) No of nursing mid wifery per: Number of nursing and midwifery personnel [Per 10,000 population],
12) No. of hospital beds: Number of hospital beds [Per 10,000 population],
13) Improved Water: Access to improved water sources [% of population],
14) Improved sanitation: Access to improved sanitation [% of population] and
15) Undernourishment: Prevalence of undernourishment [Percentage], the percentage of the population that is undernourished

We have made an attempt to find the significant factors responsible for the variation in under-5 child mortality rate among countries of Asia using linear discriminant function approach. In this paper we will use the linear discriminant analysis (LDA) as a technique for analyzing under-5 child mortality rate variation. LDA is a statistical technique designed to investigate the differences between two or more groups of people with respect to several underlying variables. Because the variable being predicted is categorical, LDA technique is more appropriate than commonly used measures. LDA performs a multivariate test of differences between groups. In addition, LDA is used to determine the minimum number of dimensions needed to describe these differences. LDA is used to analyze relationships between a response variable and predictor variables. Under-5 child mortality rate has been considered as the response variable. Since this is a discrete variable, this has been classified into three categories, that is 1)0-30, 2)31-60 and 3) 61-130. LDA analysis attempts to use the predictor variables to distinguish among the groups of the response variable. If LDA is able to distinguish among groups, it must have a strong relationship to at least one of the predictor variables. Using LDA, a series of statistical tests are conducted to test the overall relationship among the predictor variables and groups defined by the response variable.

This paper is mainly concerned with an analysis to determine if there is a significant effect of factors like GDP per capita, immunization rate, total health expenditure as % of GDP, general government health expenditure as % of total government expenditure, private health expenditure as % of total health expenditure, out-of pocket health expenditure as % of total private health expenditure, number of physicians per 10,000 population, number of nursing and midwifery persons per 10,000 population, number of hospital beds per 10,000 population, access to improved water sources and sanitation and undernourishment on under-5 child mortality rate. There are 12 predictor variables. The hypothesis of interest is: $H_0: \beta_1 = \beta_2 = \beta_3 ... = \beta_{12} = 0$;

H_a: Not all β_i equal zero. This hypothesis has been tested using LDA. The test statistic used for LDA is Wilk's Lambda $\Lambda = \prod_i \frac{1}{1+\lambda_i}$. Where λ_i are the Eigen values of the corresponding design matrices. Multinomial logistic regression has also been applied in addition to LDA. There are three main assumptions for LDA: they are 1) Multivariate Normality (MVN): To test for MVN, we begin by examining the marginal distributions of each univariate variable using box plots. If any of these plots show non-normality, then MVN is suspect and we use a procedure based on Mahalanobis distance, in which we construct a $\chi 2$ probabilities to determine conformity with multivariate normality. 2) Equality of covariance's: the test for equality of covariances is based on Box's M-test and 3) Independence of observations: This test is a function of the experimental design, or data collection method and hence is not tested. For the purposes of this paper we assume that it is true.

Empirical Results: The average under-5 mortality rate was 46 during the period 1995-2013. However, the under-5 mortality rate varied substantially across countries of Asia. On the basis of average under-5 mortality rate, countries of Asia were divided into three categories: 1) 1 to 30 2) 31 to 60 and 3) 61 to 130. The average under-5 mortality rate was 83 for the third group,43 for the second group and 16 for the first group (Table 1).Countries like Afghanistan, Pakistan, Lao PDR, Cambodia, India, Tajikistan, Bangladesh, Turkmenistan, Myanmar, Nepal and Bhutan had an average under-5 mortality rate of above 61 to 125. The average under-5 mortality rate varied between 31 to 60 for countries such as Azerbaijan, Uzbekistan, Mongolia, DPR Korea, Indonesia, Kyrgyzstan, Philippines, Kazakhstan, Turkey, Maldives and Viet Nam during the same period. On the other hand, countries like Iran, China, Georgia, Armenia, Thailand, Russian Fed., Sri Lanka, Brunei Dar., Malaysia, Rep. of Korea, Japan and Singapore had the lowest under-5 mortality rate (Figure 1).

Table 1: Summary Statistics for Under.5.mortality Rate

mort5_R	Mean	Std. Deviation	Minimum	Maximum	Kurtosis	Skewness
1	16	11	3	48	-.012	.868
2	43	17	10	94	.224	.678
3	83	27	36	149	-.753	.286
Total	46	34	3	149	-.114	.788

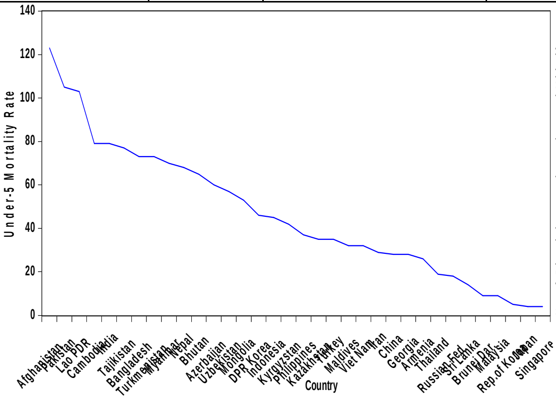

Fig 1: Average Under-5 Mortality Rate

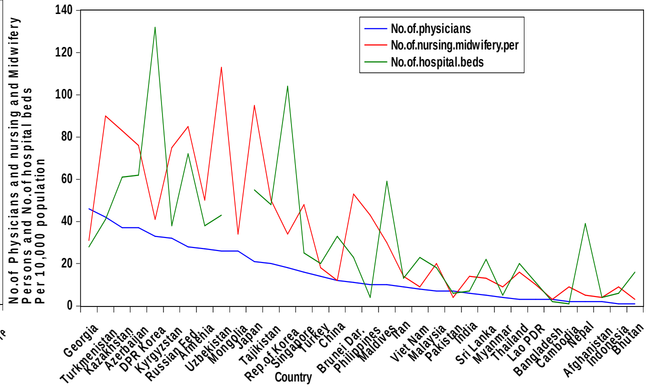

Fig 2: Average Number of Physicians, Nurses & Midwifery Persons and Beds,

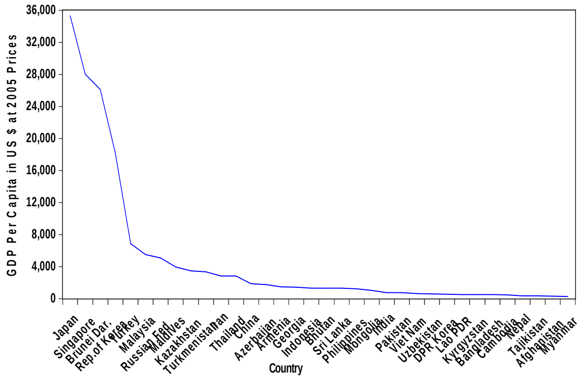

Fig 3: Average GDP Per Capita

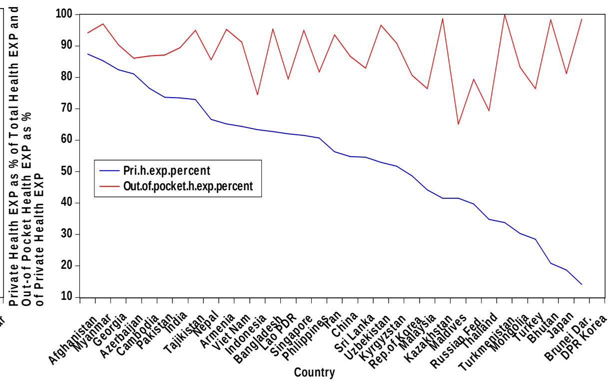

Fig 4: Average Private Health EXP as % of Total Health Exp&Out-of pocket EXP as% of Priv.H.EX

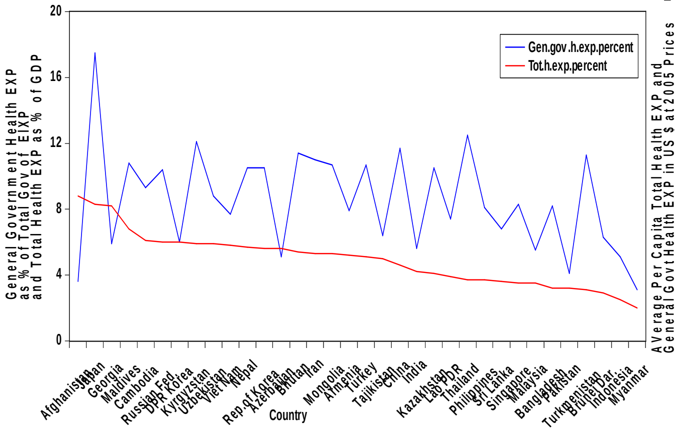

Fig 5: Average Total Health EXP as % of GDP and General Health EXP as % of totalGovt E

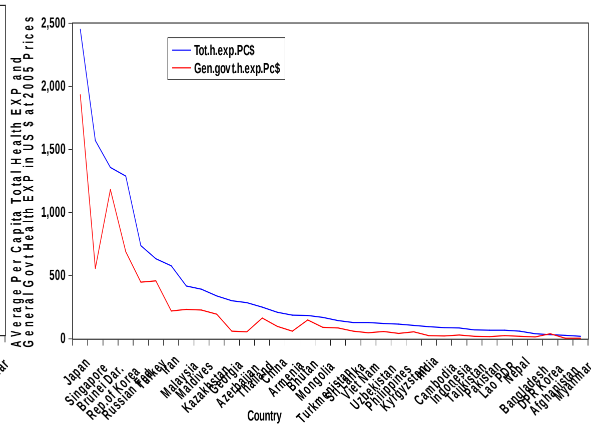

Fig 6: Average Per Capita Total H. Exp. and General Govt Health EXP in US $

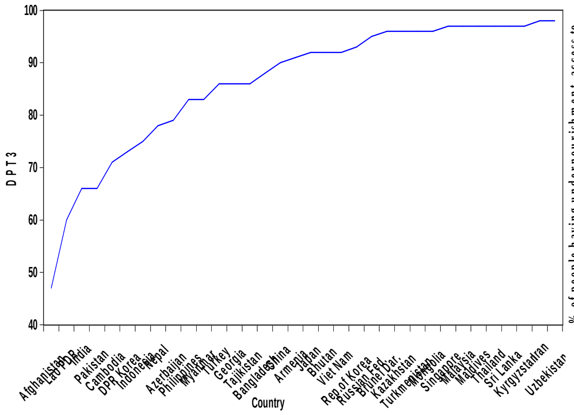

Fig 7: Average DPT3

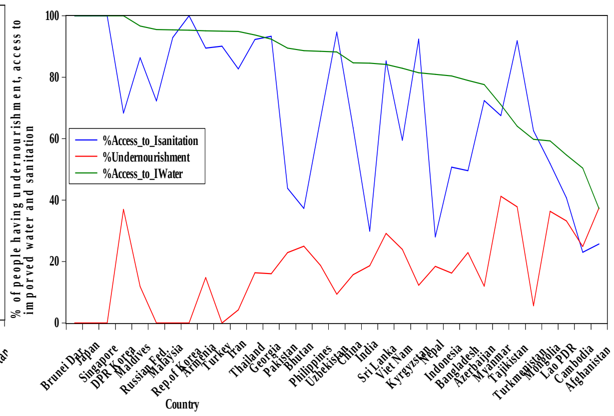

Fig 8: % of people having undernourishment, access to improved water and sanitation

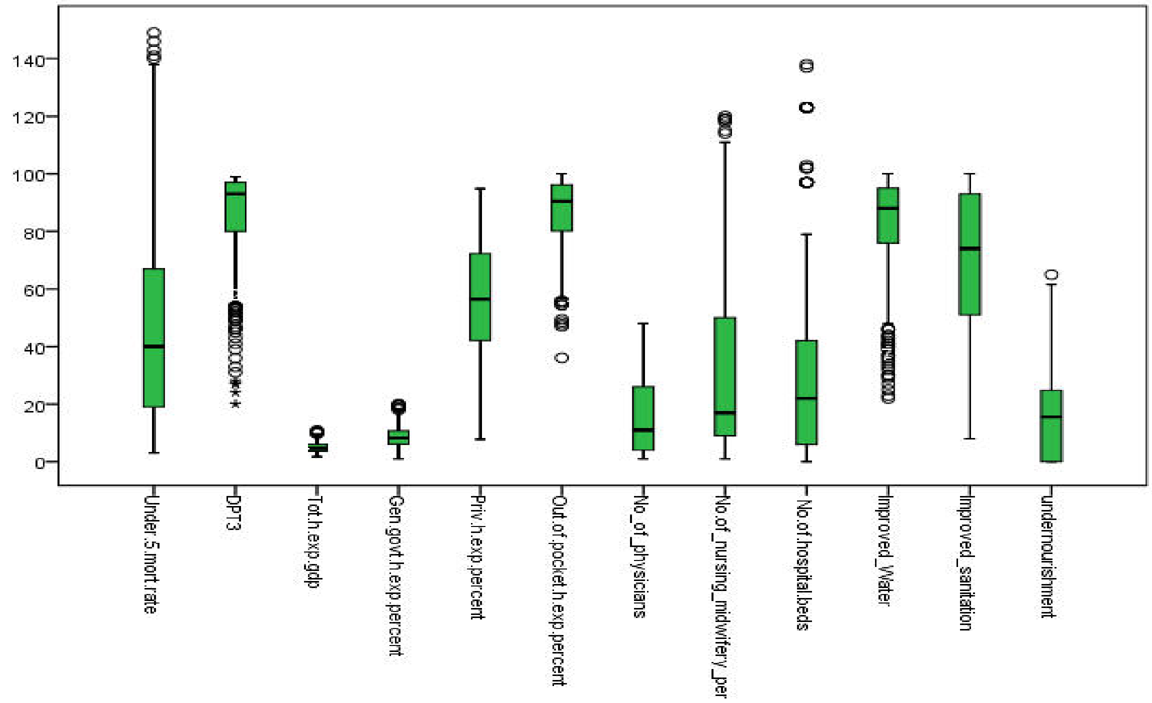

Fig 9: Plot for Mortality Rate, Health Expenditure, No. of Physicians, No. of Nursing and Midwifery Persons and No. of beds

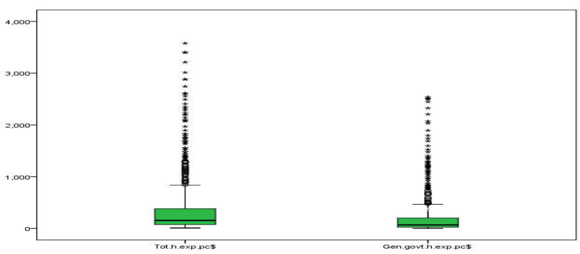

Fig10: Plot for Average Per Capita Total health EXP and General Government Health Expenditure

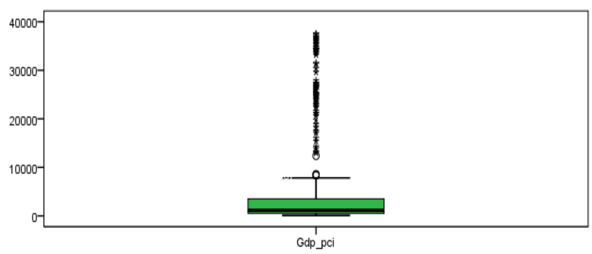

Fig 10a: Plot for Average GDP per Capita

On an average, the number of physicians per 10,000 population observed for Iran, Viet Nam, Malaysia, Pakistan, India, Sri Lanka, Myanmar, Thailand, Lao PDR, Bangladesh, Cambodia, Nepal, Afghanistan, Indonesia and Bhutan varied between 10 and 1. The average number of nurses and midwifery persons for Iran, India, Sri Lanka, China, Lao PDR, Viet Nam, Myanmar, Cambodia, Indonesia, Nepal, Pakistan, Afghanistan, Bangladesh and Bhutan varied between 14 and 3. The average number of beds per 10,000 populations varied between 7 and 1 for India, Pakistan, Indonesia, Myanmar, Philippines, Afghanistan, Bangladesh, Cambodia, and Mongolia (Figure 2). More than 65% of the total health expenditure is private in countries like Nepal, Tajikistan, India, Pakistan, Cambodia, Azerbaijan, Georgia, Myanmar, Afghanistan and DPR Korea (Figure 4). The lowest average GDP per capita, per capita total health expenditure and per capita general government health expenditure are observed for Myanmar, Afghanistan, DPR Korea, Bangladesh, Nepal, Lao PDR, Pakistan, Tajikistan, Indonesia, Cambodia and India (Figures 3 and 6). Immunization rate is less than 80% in countries like Afghanistan, Lao PDR, Pakistan, India, Cambodia, DPR Korea, Indonesia, Nepal and Azerbaijan (Figure 7). Access to improved water has been observed very low, less than 60%, for Afghanistan, Cambodia, Lao PDR, Mongolia, Turkmenistan and Tajikistan. Lowest percentage of people having access to improved sanitation is observed for Cambodia, Afghanistan, Nepal and India, less than 30%. Access to improved sanitation observed for Bhutan, Lao PDR, Pakistan, Bangladesh, Indonesia, Mongolia and Viet Nam are less than 60. Largest percentage of undernourishment has been observed for Myanmar, Tajikistan, Afghanistan, DPR Korea, Mongolia and Lao PDR (Figure 8).

Box plot presented in Figure 9 shows the presence of outliers in under-5 mortality rate, total health expenditure as % of GDP, general Government health expenditure as % of total Government expenditure, out-of pocket health expenditure as % of private expenditure, number of hospital beds, improved water and undernourishment. Under-5 mortality rate is positively skewed and the presence of higher variance is observed. Presence of variance is higher for the number of nursing and midwifery persons than the number of physicians and the number of hospital beds. Figure 10 shows the presence of outliers in average Per capita total health expenditure and general government health expenditure. Average GDP per capita also shows the presence of outliers (Figure 10a).

Table 2: Group Statistics

Predictor Variables	Group 1		Group 2		Group 3		All	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
GDP_PCI	10706.7	12051.7	2123.5	2073.3	791.1	953.1	4791.1	8622.4
DPT3	94.1	6.1	89.8	9.8	75.8	17.8	86.7	14.5
Tot.h.exp.gdp	5.0	1.9	5.1	1.5	4.6	2.0	4.9	1.8
Gen.govt.h.exp.percent	9.5	3.6	9.0	2.7	7.4	3.7	8.6	3.5
Priv.h.exp.percent	48.1	19.5	51.6	16.8	65.1	20.7	54.8	20.5
Out.of.pocket.h.exp.percent	85.8	10.1	84.5	12.7	91.7	8.2	87.4	10.8
No_of_physicians	16.9	11.8	20	13	8	12	15	13
No.of_nursing_midwifery_per	35.7	24.4	49	35	18	26	34	31
No.of.hospital.beds	37.2	33.4	32	28	16	19	29	29
Improved Water	94.2	5.9	84.3	11.0	69.0	17.8	82.8	16.3
Improved sanitation	89.2	11.7	76.1	18.1	45.4	21.7	70.6	25.5
Undernourishment	8.1	10.9	14.2	11.7	26.2	12.2	16.0	13.9

Table 3: Correlations

	Under.5.mort.rate	GDP_PCI	No_of_physicians	No.of_nursing_midwifery_per	No.of.hospital.beds	Improved Water (%)	Improved sanitation (%)	Undernourishment (%)	DPT3	Tot.h.exp.gdp	Priv.h.exp.percent
Under.5.mort.rate	1.00	-.52**	-.22**	-.25**	-.21**	-.76**	-.76**	.63**	-.73**	-.02	.44**
GDP_PCI	-.52**	1.00	.07	.35**	.16**	.42**	.48**	-.52**	.27**	.09*	-.45**
No_of_physicians	-.22**	.07	1.00	.75**	.49**	.17**	.46**	-.26**	.28**	.26**	-.10*
No.of_nursing_midwifery_per	-.25**	.35**	.75**	1.00	.40**	.20**	.55**	-.40**	.35**	.17**	-.29**
No.of.hospital.beds	-.21**	.16**	.49**	.40**	1.00	.29**	.33**	-.15**	.12**	.21**	-.18**
Improved Water	-.76**	.42**	.17**	.20**	.29**	1.00	.64**	-.62**	.54**	-.07	-.41**
Improved sanitation	-.76**	.48**	.46**	.55**	.33**	.64**	1.00	-.55**	.65**	.01	-.36**
undernourishment	.63**	-.52**	-.26**	-.40**	-.15**	-.62**	-.55**	1.00	-.49**	-.05	.47**
DPT3	-.73**	.27**	.28**	.35**	.12**	.54**	.65**	-.49**	1.00	-.07	-.53**
Tot.h.exp.gdp	-.02	.09*	.26**	.17**	.21**	-.07	.01	-.05	-.07	1.00	.05
Gen.govt.h.exp.percent	-.29**	.32**	.15**	.30**	.17**	.19**	.21**	-.34**	.38**	.35**	-.62**
Priv.h.exp.percent	.44**	-.45**	-.10*	-.29**	-.18**	-.41**	-.36**	.47**	-.53**	.05	1.00
Out.of.pocket.h.exp.percent	.23**	-.01	.21**	.21**	-.06	-.19**	-.07	.13**	-.04	-.05	.19**

**.Correlation is significant at the 0.01 level (2-tailed),*.Correlation is significant at the 0.05 level (2-tailed).

Group statistics for predictor variables are presented in Table 2. The average number of physicians per 10,000 populations is 8 for group 3, 19 for group 2 and 17 for group 1. The average number of nursing and midwifery persons per 10,000 populations was 18 for group 3, 51 for group 2 and 38 for group 1. The average number of beds per 10,000 populations is 16 for group 3, 35 for group 2 and 37 for group 1 (Table 2). Under-5 mortality rate is negatively correlated with GDP per capita, immunization rate, per capita total health expenditure, per capita general government health expenditure, number of physicians, number of nurses and midwifery persons, the number of hospital beds per 10000 population, % of people having access to improved sanitation and improved water and positively related to % undernourishment (Table 3).

LDA Results: The minimum ratio of valid cases to predictor variables for LDA is 5 to 1. In this case, it is 626/12 ≈ 52 to 1, which satisfies the minimum requirement and also does satisfy the preferred ratio of 20 to 1 (Table 4). The number of cases in the smallest group in this problem is 190, which is larger than the number of predictor variables (12), satisfying the minimum requirement. In addition, the number of cases in the smallest group satisfies the preferred minimum of 20 cases (Table 5).In this analysis there were 3 groups defined by category of under-5 child mortality rates, 12 predictor variables, so the maximum possible number of discriminant functions was 2. The canonical correlations for the dimensions one and two are 0.805 and 0.572, respectively (Table 6). In the table of Wilk's lambda which tested functions for statistical significance, the stepwise analysis identified 2 discriminant functions that were statistically significant. The Wilk's lambda statistic for the test of function 1 through 2 functions (chi-square=892.00) had a probability of 0.000 which was less than the level of significance of 0.05. The Wilk's lambda statistic for the test of function 2 (chi-square=244.76) had a probability of 0.000 which was less than the level of significance of 0.05. The significance of the maximum possible number of discriminant functions supports the interpretation of a solution using 2 discriminant functions (Table 7). Table 8 shows unstandardized canonical discriminant functions evaluated at group means. Function 1 separates the under-5 child mortality rate category 3 (the negative value of 1.753) from child mortality rate category 1(positive value of 1.492) and child mortality category 2 (positive value of 0.146). Function 2 separates the child mortality rate category 2 (the negative value of 1.050) from child mortality rate category 1(positive value of 0.514) and child mortality category 3 (positive value of 0.396).

Table 4:Analysis Case Processing Summary

Unweighted Cases		N	Percent
Valid		626	96.9
Excluded	Missing or out-of-range group codes	0	.0
	At least one missing discriminating variable	20	3.1
	Both missing or out-of-range group codes and at least one missing discriminating variable	0	.0
	Total	20	3.1
Total		646	100.0

Table 5:Prior Probabilities for Groups

mort5_R	Prior	Cases Used in Analysis	
		Unweighted	Weighted
1	.333	227	227.000
2	.333	190	190.000
3	.333	209	209.000
Total	1.000	626	626.000

Table 6:Eigenvalues

Function	Eigen value	% of Variance	Cumulative %	Canonical Correlation
1	1.848[a]	79.2	79.2	.805
2	.485[a]	20.8	100.0	.572

a. First 2 canonical discriminant functions were used in the analysis.

Table 7:Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	.236	892.002	20	.000
2	.673	244.758	9	.000

Table 8:Functions at Group Centroids

mort5_R	Function	
	1	2
1	1.492	.514
2	.146	-1.050
3	-1.753	.396

Unstandardized canonical discriminant functions evaluated at group means

At each step, the variable that maximizes the Mahalanobis distance between the two closest groups is entered. When we use the stepwise method of variable inclusion, we limit our interpretation of predictor variables to those listed as statistically significant in the table of variables Entered/Removed (Table 9). We will interpret the impact on membership in groups defined by the response variable by the predictor variables:1)Improved water, 2)GDP per capita, 3)Number of nurses and midwifery persons, 4)Improved sanitation,5)Number of physicians, 6)Out-of pocket health expenditure, 7)Number of hospital beds, 8)general government health expenditure as % of total expenditure, 9)total health expenditure as % of GDP, and 10)private health expenditure as % of total health expenditure. Differences in under-5 child mortality rate observed between groups 1 and 2 are mainly caused by Improved water, number of nurses and midwifery persons, improved sanitation, number of physicians, out-of pocket health expenditure, number of hospital beds, general government health expenditure as % of total expenditure, total health expenditure as % of GDP, and private health expenditure as % of total health expenditure. (Table 9). Similarly, differences in under-5 child mortality rate observed between groups 2 and 3 are mainly caused GDP per capita. Using Wilk's lambda and step-wise LDA, the variables that minimizes the overall Wilk's lambda is entered. In our case, improved sanitation, improved water, undernourishment, immunization rate, GDP per capita, number of nursing and midwifery persons and number of physicians are important and significant(Table 10).

Table 9:Variables Entered/Removed

Step	Entered	Removed	Min. D Squared						
			Statistic	Between Groups	Exact F Statistic	df1	df2	Sig.
1	Improved Water		.629	1 and 2	65.010	1	623.000	3.826E-15
2	GDP_PCI		1.512	2 and 3	75.140	2	622.000	5.901E-30
3	No.of_nursing_midwifery_per		2.557	1 and 2	87.887	3	621.000	2.082E-47
4	Improved_sanitation		3.367	1 and 2	86.654	4	620.000	1.830E-58
5	No_of_physicians		3.861	1 and 2	79.346	5	619.000	2.732E-64
6	Out.of.pocket.h.exp.percent		3.990	1 and 2	68.225	6	618.000	4.816E-65
7	No.of.hospital.beds		4.109	1 and 2	60.131	7	617.000	1.122E-65
8	Gen.govt.h.exp.percent		4.173	1 and 2	53.350	8	616.000	1.329E-65
9	Tot.h.exp.gdp		4.175	1 and 2	47.367	9	615.000	9.489E-65
10		Gen.govt.h.exp.percent	4.123	1 and 2	52.703	8	616.000	6.013E-65

At each step, the variable that maximizes the Mahalanobis distance between the two closest groups is entered.

Table 10:Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
GDP_PCI	.728	116.398	2	623	.000
DPT3	.702	132.520	2	623	.000
Tot.h.exp.gdp	.986	4.351	2	623	.013
Gen.govt.h.exp.percent	.933	22.460	2	623	.000
Priv.h.exp.percent	.869	46.757	2	623	.000
Out.of.pocket.h.exp.percent	.918	27.994	2	623	.000
No_of_physicians	.855	52.786	2	623	.000
No.of_nursing_midwifery_per	.842	58.295	2	623	.000
No.of.hospital.beds	.904	33.120	2	623	.000
Improved_Water	.582	223.783	2	623	.000
Improved sanitation	.468	354.302	2	623	.000
undernourishment	.697	135.424	2	623	.000

Table 11:Structure Matrix

	Function	
	1	2
Improved sanitation	.778*	-.191
Improved Water	.623*	-.029
undernourishment[b]	-.424*	.106
DPT3[b]	.422*	-.203
Priv.h.exp.percent	-.278*	.120
No.of.hospital.beds	.236*	-.089
Gen.govt.h.exp.percent	.194*	-.071
No.of_nursing_midwifery_per	.205	-.475*
GDP_PCI	.400	.400*
No_of_physicians	.234	-.375*
Out.of.pocket.h.exp.percent	-.183	.240*
Tot.h.exp.gdp	.075	-.086*

b. This variable not used in the analysis.

Table 12:Standardized Canonical Discriminant Function Coefficients

	Function	
	1	2
GDP_PCI	.301	.889
Tot.h.exp.gdp	.151	-.177
Gen.govt.h.exp.percent	.103	.239
Priv.h.exp.percent	-.028	.288
Out.of.pocket.h.exp.percent	-.257	.519
No_of_physicians	.435	.220
No.of_nursing_midwifery_per	-.608	-1.251
No.of.hospital.beds	.013	.198
Improved_Water	.325	-.164
Improved_sanitation	.785	.060

Based on the structure matrix, the predictor variables strongly associated with discriminant function 1 which distinguished between under-5 child mortality rate categories are improved sanitation(r=0.778),improved water (r=0.623) and GDP per capita(r=0.400).Based on the structure matrix, the predictor variable strongly associated with discriminant function 2 which distinguished between under-5 child mortality rate categories are GDP per capita (r=0.400), the number of nurses and midwifery persons(r=-0.475) and the number of physicians (r=-0.375) (Table 11).The number of discriminant dimensions is the number of groups minus 1. However, some discriminant dimensions may not be statistically significant. In this example, there are two discriminant dimensions, both of which are statistically significant. The Coefficients of linear discriminant are reported in Table 12. The equations of the linear discriminant function are:

1) Discriminant_score_1=0.301*GDP_PCI+0.151Tot.h.exp.gdp+0.103gen.govt.h.exp.percent
-0.028priv.h.exp.percent-0.257out.of.pocket.h.exp.percent+0.435no_of_physians
-0.608No.of.nursing.midwifery.per+0.013No.of.hospital.beds+0.325improved_water
+0.785improved_sanitation

2) Discriminant_score_2 =0.889*GDP_PCI-1.77Tot.h.exp.gdp+0.239gen.govt.h.exp.percent
+0.288priv.h.exp.percent+0.519ut.of.pocket.h.exp.percent+0.220no_of_physians
-1.251No.of.nursing.midwifery.per+0.198No.of.hospital.beds-0.1640improved_water
+0.060improved_sanitation

As you can see, the under-5 child mortality rate categories 2 and 3 tend to be less at the number of nurses and midwifery persons(negative)and category 1 tend to me more at the GDP per capita, improved sanitation and water and number of physicians on dimension 1. On dimension 2, the under-5 child mortality rate categories 2 and 3 tend to be lower on the number of nurses and midwifery persons and category 1 tend to be more at the GDP per capita (Fig 11).

Figure 11:Canonical Discriminant Functions

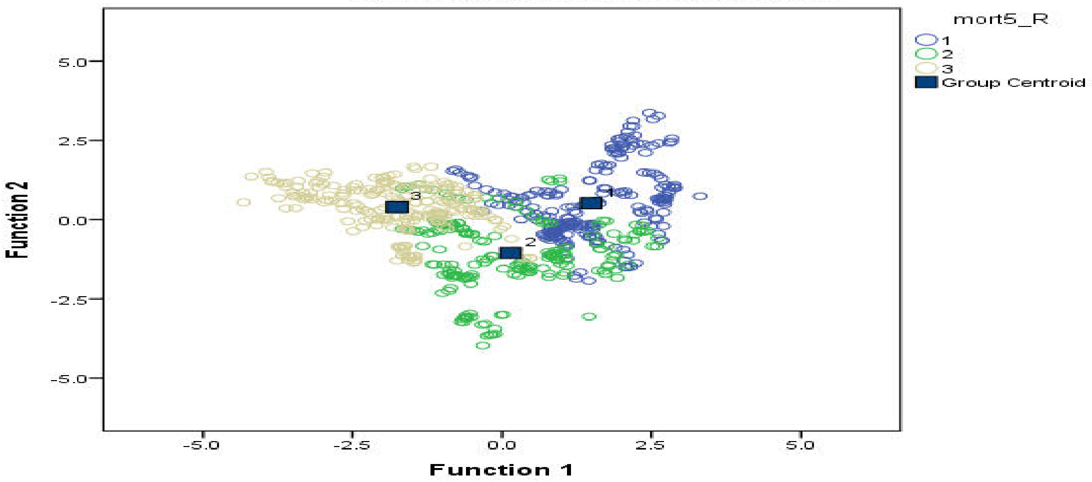

Table 13:Classification Results[a,c]

		mort5_R	Predicted Group Membership 1	2	3	Total
Original	Count	1	181	37	9	227
		2	37	116	37	190
		3	0	17	192	209
	%	1	79.7	16.3	4.0	100.0
		2	19.5	61.1	19.5	100.0
		3	.0	8.1	91.9	100.0
Cross-validated[b]	Count	1	177	41	9	227
		2	38	114	38	190
		3	0	23	186	209
	%	1	78.0	18.1	4.0	100.0
		2	20.0	60.0	20.0	100.0
		3	.0	11.0	89.0	100.0

a. 78.1% of original grouped cases correctly classified.
b. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.
c. 76.2% of cross-validated grouped cases correctly classified.

The cross validated accuracy rate computed by SPSS was 78.1% which was greater than the proportional by chance accuracy criteria of 41.3% (1.25*33.0=41.3). The criteria for classification accuracy is satisfied (Table 13). The proportional by chance accuracy rate was computed by squaring and summing the proportion of cases in each group from the table of prior probabilistic for groups (0.333^2 + 0.333^2 + 0.333^2 =33.0).

Apart from linearity the main assumptions in lda are: 1) MVN errors: The first assumption can be checked using Mahalanobis plot although symmetry is probably more important. The plot of ordered Mahalanobis distances against their expected values under the assumption of Multivariate Normality shows slight deviation from straight line. However, we conclude that the assumption of multivariate normality is approximately upheld (Fig.12).

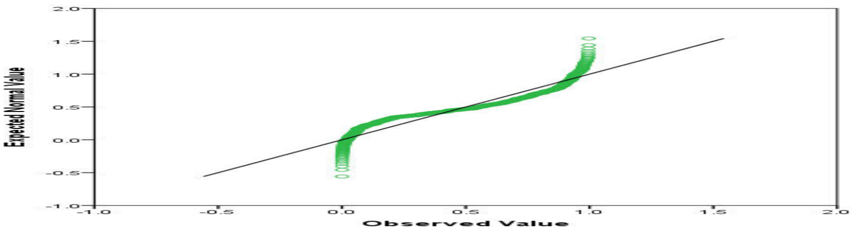

Fig.12: Normal Q-Q Plot for Multivariate Data

Table 14:Test Results

Box's M		4104.837
F	Approx.	36.476
	df1	110
	df2	1011483.487
	Sig.	.000

Tests null hypothesis of equal population covariance matrices.

2) Box's Test of Equality of Covariance Matrices: For the second assumption there is a test of equality of covariance's matrices, Box's M test. Violation of this assumption can affect significance tests of classification results. The significance level can be inflated (false positives) when the number of variables is large and the sample sizes of the groups differ, quadratic methods can be used if the covariance matrices are unequal but a large number of parameters are involved and lda is thus superior for small sample sizes. Overall lda is robust to both the assumption of MVN and equality of covariance matrices, especially if the sample sizes are equal. The formal hypothesis for Box's M test for Equality of covariance would be: $H_0: \Sigma 1 = \Sigma 2 = \Sigma 3$, $H_0: \Sigma 1 \neq \Sigma 2 \neq \Sigma 3$

$\alpha = 0.05$, $Fobs = \frac{MS_{Regression}}{MS_{Residual}}$

Reject H_0 if p-value <0.05

Reject H_0 asp-value = 0.000<0.05

Tests null hypothesis of equal population covariance matrices

Test Statistic

$$M = \sum n_i \ln|s| - \sum_{i=1}^{k} n_i \ln|s_i|$$

$$C^{-1} = 1 - \frac{2p^2+3p-1}{6(p+1)(k-1)}\left(\sum_{n-1}^{k}\frac{1}{n_i} - \frac{1}{\sum n_i}\right)$$

Sampling Distribution

$$MC^{-1} \sim \frac{\chi^2 (k-1)(p)(p+1)}{2} \text{ if } k, p < 5 \text{ and } n_i \approx 20 \text{ else F distribution}$$

To test the assumption of Equality of Co-variances, we use Box's M-test. If the Box's M Test shows p<.05, the covariance's are significantly different and the null hypothesis is NOT rejected. If the Box's M Test shows p >.05, the covariance's are not significantly different and the null hypothesis is rejected. The value of Box's M is 4104.84, with a p-value of 0.000, indicating that the assumption of equal co-variances is not satisfied and null hypothesis is not rejected. So the assumption of homoscedasticity is violated. That is we do not reject the null hypothesis of $H_0: \Sigma 1 = \Sigma 2 = \Sigma 3$.Thus, only one assumption, namely, multivariate normality is satisfied and the other assumption, equality of covariance matrices, is not satisfied.

Multinomial Logistic Regression Results: We also ran multinomial logistic regression using the same variables used in LDA. Here, we see model fit is significant, $\chi 2$ (8) =450.62, p<0.001. Which indicates our full model predicts significantly better, or more accurately, than the null model (Table 15). Both the Pearson and Deviance statistics are chi-square based methods and here we interpret lack of significance as indicating good fit (Table 16). Higher values of Pseudo R-square indicate better fit (Table 17). The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0. We can see from the table that all predictors display a significant chi-square which indicates that model is significant (Table 18).

Table 15:Model Fitting Information

	Model Fitting Criteria	Likelihood Ratio Tests		
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1372.174			
Final	450.562	921.613	24	.000

Table 16:Goodness-of-fit

	Chi-Square	df	Sig.
Pearson	840.296	1226	1.000
Deviance	450.562	1226	1.000

Table 17:Pseudo R-Square

Cox and Snell	.771		
Nagelkerke	.867		
McFadden	.672		

Table 18:Likelihood Ratio Tests

	Model Fitting Criteria	Likelihood Ratio Tests		
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	545.681	95.119	2	.000
DPT3	491.151	40.589	2	.000
GDP_PCI	591.432	140.870	2	.000
Tot.h.exp.gdp	507.935	57.374	2	.000
Gen.govt.h.exp.percent	474.162	23.601	2	.000
Priv.h.exp.percent	490.479	39.917	2	.000
Out.of.pocket.h.exp.percent	568.852	118.290	2	.000
No_of_physicians	497.351	46.789	2	.000
No.of_nursing_midwifery_per	589.897	139.335	2	.000
No.of.hospital.beds	475.647	25.085	2	.000
Improved_Water	488.694	38.133	2	.000
Improved_sanitation	486.446	35.885	2	.000
undernourishment	458.139	7.577	2	.023

Table 19:Parameter Estimates

mort5_R[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
2	Intercept	36.153	5.272	47.032	1	.000			
	DPT3	-.152	.030	25.206	1	.000	.859	.809	.911
	GDP_PCI	-.001	.000	44.299	1	.000	.999	.999	1.000
	Tot.h.exp.gdp	1.261	.210	36.137	1	.000	3.530	2.340	5.326
	Gen.govt.h.exp.percent	-.378	.086	19.049	1	.000	.686	.579	.812
	Priv.h.exp.percent	-.117	.023	25.435	1	.000	.889	.850	.931
	Out.of.pocket.h.exp.percent	-.029	.019	2.284	1	.131	.971	.936	1.009
	No_of_physicians	-.229	.046	24.476	1	.000	.795	.726	.871
	No.of_nursing_midwifery_per	.166	.022	55.988	1	.000	1.181	1.130	1.233
	No.of.hospital.beds	-.038	.009	17.506	1	.000	.963	.946	.980
	Improved_Water	-.118	.038	9.421	1	.002	.889	.825	.958
	Improved_sanitation	-.044	.016	7.282	1	.007	.957	.926	.988
	undernourishment	-.072	.027	6.793	1	.009	.931	.882	.982
3	Intercept	30.356	6.292	23.279	1	.000			
	DPT3	-.187	.035	28.262	1	.000	.829	.774	.888
	GDP_PCI	-.001	.000	10.059	1	.002	.999	.998	1.000
	Tot.h.exp.gdp	.758	.240	9.967	1	.002	2.134	1.333	3.418
	Gen.govt.h.exp.percent	-.363	.111	10.718	1	.001	.696	.560	.865
	Priv.h.exp.percent	-.079	.027	8.838	1	.003	.924	.877	.973
	Out.of.pocket.h.exp.percent	.222	.038	34.725	1	.000	1.249	1.160	1.344
	No_of_physicians	-.326	.059	30.836	1	.000	.722	.643	.810
	No.of_nursing_midwifery_per	.182	.025	51.514	1	.000	1.199	1.141	1.260
	No.of.hospital.beds	-.053	.014	14.729	1	.000	.949	.924	.975
	Improved_Water	-.210	.041	25.910	1	.000	.810	.747	.879
	Improved_sanitation	-.115	.022	28.275	1	.000	.891	.854	.930
	undernourishment	-.083	.036	5.373	1	.020	.921	.858	.987

a. The reference category is: 1.

The Wald test (and associated p-value) is used to evaluate whether or not the logistic coefficient is different than zero. We can see that one unit change in Out.of.pocket.h.exp.percent do not significantly change the odds of being classified in the first category of the outcome variable relative to the second category of the outcome variable while controlling for the influence of the other predictors. The B coefficients of variables like immunization rate, general government health expenditure as % of total government expenditure, number of physicians per 10,000 population, number of hospital beds per 10,000 population, access to improved water and sanitation are significant and shows expected negative sign for category 2 as well as category 3 indicating that increasing the value of these predictors is associated with decreased odds of achieving lower under-5 child mortality. The variables associated with significant negative coefficients have a significant effect on changing the odds of being classified in the first category of the outcome variable relative to the second and third categories of the outcome variable while controlling for the influence of the other predictors. Logistic regression also satisfies main assumptions of the model such as linearity, independence of errors and absence of multicollinearity.

Table 20: Classification

Observed	predicted			
	1	2	3	4
1	209	15	3	92.1%
2	26	141	23	74.2%
3	1	18	190	90.9%
Overall percentage	37.7%	27.8%	34.5%	86.3%

The Classification Table (above) shows how well our full model correctly classifies cases. The key piece of information is the overall percentage in the lower right corner which shows our model (with all predictors & the constant) is 86.3% accurate which is excellent (Table 20).

Conclusion: Using the LDA technique for countries in Asia for the period 1995-2013, the study has shown that significant discriminatory factors responsible for the variation in under-5 child mortality rate are improved water and sanitation, GDP per capita, number of physicians and number of nurses and midwifery persons. This means that, in general, the higher under-5 child mortality rate observed for countries like Afghanistan, Pakistan, Lao PDR, Cambodia, India, Tajikistan, Bangladesh, Turkmenistan, Myanmar, Nepal and Bhutan are due to lower GDP per capita, poor access to the improved water and sanitation, lower number of physicians, and lower number of nurses and midwifery persons. So in order to reduce under-5 child mortality rate for countries in second and third categories of Asia, GDP per capita, number of physicians and number of nurses and midwifery persons need to be increased as well as coverage of access to improved water and sanitation need to be expanded. Multinomial logistic regression shows the variables like immunization rate, general government health expenditure, number of physicians per 10,000 populations, number of hospital beds per 10,000 population, access to improved water and sanitation are significant negatively for categories 2 and 3 indicating that increasing the value of these predictors is associated with decreased odds of achieving lower under-5 child mortality

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