South University of Science and Technology

On Global Child Mortality

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Course: MA304 Multivariate Statistical Analysis

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1 Abstract

Objective To identify the regional patterns of the under-five rate (U5MR) in 143 countries, to find the influencing factors of U5MR, to modeling UM5R, and to provide recommendations to reducing U5MR in the future. **Methods** ANOVA and MANOVA are used to compare means in different regions and U5MR groups. Linear regression method is used for modelling the relationship between U5MR and influencing factors. **Results** U5MR is low in most of Europe and Central Asia and North America countries, while it is high in most of Sub-Saharan countries. Education expenditure, GDP per capita, public health expenditure, immunizations of DPT and measles negatively relate to U5MR, and fertility rate negatively relate to U5MR. The model given can explain most of variation in data (R^2_{adj}=0.879). **Conclusions** Child mortality is a serious issue especially in Sub-Saharan. To promote child well-being, countries should try to increase people's wealth, public health inputs, and promote child immunizations and control fertility rate.

2 Introduction

In September 2000, world leaders signed The *United Nations Millennium Declaration* and agreed to try to achieve eight Millennium Development Goals (MDGs) by the year 2015 [1]. The MDG 4 calls for reducing the under-five rate (U5MR) by two-thirds between 1990 and 2015 [1]. The world has made substantial progress, reducing the rate 49 percent, from 90 (89, 92) deaths per 1,000 live births in 1990 to 46 (44, 48) in 2013 [1]. However, the world did not realize the goal by 2015 [2]. As a key indicator of child well-being and social and economic development, the U5MR rate is of great significance to study. Thus, this study mainly analyzes the global data of U5MR in 2010 from World Bank [3], and aims to identify the regional difference of U5MR, to explore the relationships between U5MR and other factors, to modeling U5MR, and to provide recommendations to reducing U5MR in the future.

3 Materials and Methods

3.1 Data

Data used in the study is extracted from World Bank (2010) [3]. The dataset contains data of 143 countries and 27 variables related to geographic location, education, economy, health, demographic structure, agriculture, fertility, life expectancy, and mortality.

Haiti and Pakistan are excluded in analysis, because some infrequent and serious natural disasters happened in these countries in 2010, which caused unusually high mortality. The details are given in 4.1.

3.2 Classification

3.2.1 Classification by region

The study classifies 143 countries to seven groups by geographic location. That is, 17 countries in East Asia and Pacific (EAP) group, 41 countries in Europe and Central Asia (ECA) group, 24 countries in Latin America and Caribbean (LAC) group, 13 countries in Middle East and North Africa (MENA) group, 2 countries in North America (NA) group, 7 countries in South Asia (SA) group, and 39 countries in Sub-Saharan Africa (SSA) group.

3.2.2 Classification by U5MR

Divide countries into three groups by the level of U5MR. Specifically, 46 countries are in high level (U5MR$\geqslant$40‰) group, 54 countries are in medium level (10‰<U5MR$\leqslant$40‰) group, and 43 countries are in low level (U5MR$\leqslant$10‰) group [4].

3.3 Statistical Analysis

Under normality and homoscedasticity assumptions, check the equality of U5MR among different regions with ANOVA, and F-value is 38.06 and the p-value is less than 2e-16. The result means that U5MR among different regions are significantly different. Hence, it is reasonable to breakdown countries by geographic location. ANOVA and

MANOVA are used in section 4 to compare the factors' means in different U5MR groups, with normality and homoscedasticity assumptions. In section 5, a linear regression model is set up to define the relationships between U5MR and influencing factors.

4 Findings

4.1 Geographic patterns of child mortality

Haiti has the highest U5MR among all the countries(175.1‰), following by Angola (173.1‰), and Chad (159‰). It is noteworthy that nine out of the ten countries with highest U5MR are in Sub-Saharan Africa, indicating tough situation faced by children in Sub-Saharan Africa. According to UNICEF, pneumonia, diarrhea and malaria are the leading causes of death among children under age 5 [5]. Thus, poor sanitation, malnutrition and lack of medical treatment can be explanations for high U5MR in SSA region. In addition, sustained civil wars and conflicts in this region may directly and indirectly cause mass child mortality. However, why is Haiti, a country in Latin America, with the highest U5MR? In 2010, Haiti experienced a severe cholera outbreak that caused 8,183 deaths and an earthquake killing over 300,000 people [6][7]. These events resulted in extremely high U5MR in Haiti in 2010. Therefore, the high U5MR in Haiti should be considered as an exception and should not be used to determine the patterns of global child mortality. Figure 1 illustrates the U5MR in each region and reflect the difference among regions.

Table 1 shows the U5MR levels and the number of countries in different regions, with the exclusion of Haiti. From Table 1, we can see that U5MR levels have similar numbers of countries while the numbers of countries vary much in different regions. In North America, there are only two countries, United State and Canada, and both of them have low U5MR. This is easy to understand since both countries are developed and with mature health care systems. Also, none of ECA country is in high U5MR group,

indicating ECA countries put emphasis on child well-being. LAC and MENA groups show similar pattern that most of countries concentrate in the medium U5MR group. Except Haiti, the only high U5MR country in LAC is Bolivia, with U5MR 44.9‰, which is closed to medium level and is much lower than Haiti (U5MR 175.1‰). This indicates again that it is reasonable to exclude Haiti in further analysis. The only high U5MR country in MENA is Yemen, with U5MR 64.3‰. The Sa' dah Insurgency (2004-2010) is a possible reason for high child mortality rate in Yemen. SA and SSA are two regions need most concern, since most of countries in these regions are with high U5MR, and none of them is in low U5MR group. As the country with highest U5MR in SA group, Pakistan shows unusual high U5MR (90‰), which is much higher than the second, India (U5MR 61.2 ‰). The Pakistan floods of 2010 that affected approximately 20 million people might account for the high mortality rate [8]. Therefore, Pakistan should also be excluded from analysis. In SSA, as mentioned above, poor sanitation, malnutrition and lack of medical treatments account for the serious situation of child well-being.

Group	EAP	ECA	LAC (Exclude Haiti)	MENA	NA	SA (Exclude Pakistan)	SSA	Total
Low	6	30	2	3	2	0	0	43
Medium	9	11	20	9	0	2	3	54
High	2	0	1	1	0	4	36	44
Total	17	41	23	13	2	6	39	141

Table 1

4.2 Factors related to child mortality

4.2.1 Education and child mortality

This report assesses education condition of countries using "Adjusted savings: educational expenditure (% of GNI)" (EE) from the World Bank [3]. Education expenditure refers to the current operating expenditures in education including wages and salaries and excluding capital investments in buildings and equipment [9]. Thus, it is a good indicator of national situation.

The results show that education expenditure negatively relate to U5MR (r=-0.296). ANOVA test indicates that education expenditure is significantly different among U5MR groups (F=9.847, P= 0.0001). Figure2 shows that on average, countries in lower level of the U5MR tend to have higher education expenditure. Respectively, the mean education expenditure of low, medium, high level groups is 5.157,3.944 and 3.719 (% of GNI). This finding is consistent with the finding of Our World in Data that better education of women reduces child mortality [10]. According to Our World in Data, maternal education can reduce teenage pregnancy, and thus greatly reduces the risk of child mortality [10]. However, despite high education expenditure, Lesotho and Burundi are in high U5MR level. The second highest HIV prevalence in the world might be the reason for high child mortality in Lesotho [11]. As for Burundi, where children suffer from civil war and diseases, the high education expenditure is the effort of government to reduce child mortality [12].

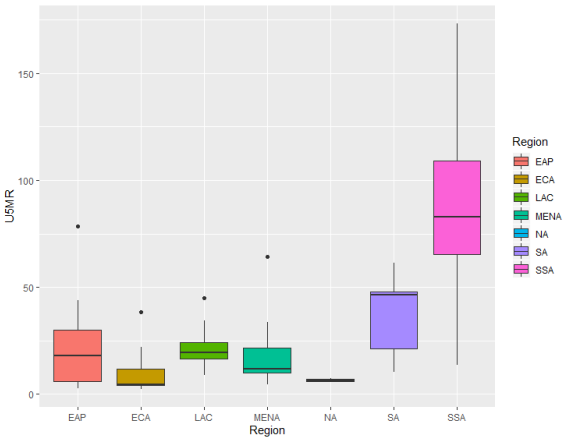

Figure 1

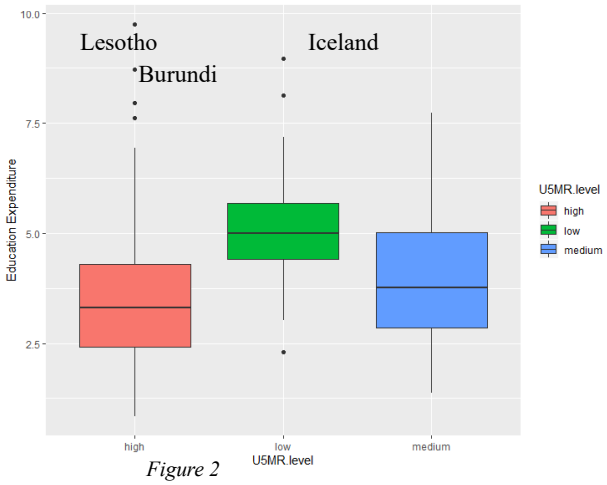

Figure 2

4.2.3 Fertility and child mortality

The fertility rate is number of live births per women. Result of ANOVA suggests significant difference fertility rate mean among U5MR groups ($F=145.3$, $P<2e\text{-}16$). Furthermore, the high relation coefficient of fertility and child mortality ($r=0.867$) suggests a strong positive relationship between them, so the countries with high fertility rate tend to have high child mortality rate. However, the relationship varies much among U5MR groups. The relationship in high level group is strong ($r=0.724$), while it is much weaker in low level group ($r=0.086$), and the medium level group appears moderate relationship ($r=0.405$). Figure 3 shows the U5MR rate and fertility rate of countries in three U5MR level groups and fitting lines for each group. The U5MR in all groups show an uptrend as fertility rate grows. While the numbers of countries in each group are almost the same and common, we can see that countries in high level group distribute sparsely and countries in low level group distribute densely. This explains why correlation differ. In addition, relationship of U5MR and the adolescent fertility rate (births per 1000 women ages 15-19) appear similar patterns.

The causal link between child mortality and fertility is established in both directions: Firstly, decreasing child mortality reduces the parents' demand for children. Secondly, a decreasing fertility allows the parents to devote more attention and resources to their children [10].

4.2.4 Wealth and child mortality

There are several indicators for national wealth level, such as GDP, GDP growth, and GDP per capita, PPP (PPP). Apply MANOVA to see if mean vectors of three indicators from different U5MR groups are equal. The results suggest that the mean vectors are different ($p<2.2e\text{-}16$) and that each indicator (GDP, GDP growth, and PPP is different among groups ($p=0.0054$, $p=0.0003$ $p<2.2e^{-16}$, respectively). Since PPP is

widely considered to be the best indicator of standard of living, this section focuses on the relation between PPP and U5MR in different U5MR groups.

The mean PPP of low, medium and high U5MR group is 27747, 9906, and 2513.3 (international$), respectively. It is obvious that a country in the group with higher PPP is likely has lower child mortality rate. Figure 4 shows that, overall, in each group, the U5MR decreases as PPP rises. Moreover, the high U5MR group shows a sharp decline in U5MR as PPP increases. Without doubt, better economic condition and higher standard of living means better health care and nutrition, which leads to child well-being. For the countries in high U5MR group, the PPP is too low to meet people basic need, thus child mortality would rapidly increase as PPP grows. Therefore, to reduce child mortality in high U5MR countries, it is crucial to develop the economy and improve the living standard of people.

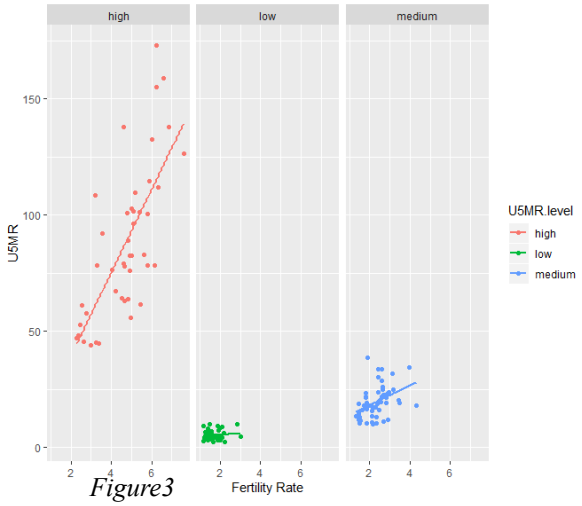

Figure3

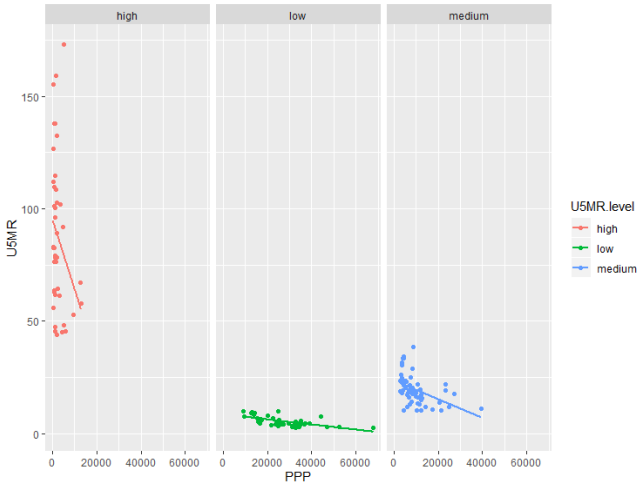

Figure 4

4.2.5 Public health and child mortality

Since there is a large number of children died from diseases globally, it is necessary to examine the relationship between public health and child mortality. Public health expenditure is a good indicator for country's emphasis on public health, so the proportion of public health expenditure in GDP (HEP, % of GDP) is used in this section. Also, vaccination is widely considered as an effective method to protect child against

the diseases. The DPT is an immunization or vaccine to protect against diphtheria, pertussis, and tetanus. In this section, the relationship between child mortality and the immunization of DPT and measles (% of children age12-23 months) is also explored.

Figure 5 shows the HEP of three U5MR groups and it is obvious that the higher U5MC a group is, the lower its HEPC is. This indicates that countries should increase the health care input to reduce child mortality. Unexpectedly, Lesotho and Costa Rica, which are from high U5MR and medium U5MR groups, appear to have high HEP above the median HEP of low U5MR group. Low GDP (176.6 million US$, in 2005, rank 16 among 141 countries [3]) can account for high HEP in Lesotho. As for Costa Rica, its U5MR (10.3 per 1000 live births) is lower than most of countries in medium group, consistent to the conclusion above.

Table 2 exhibits the DPT and measles immunization of each U5MR group. The patterns of two immunizations are similar. One explanation is that a country that promote the vaccine against a childhood disease tends to promote vaccine against other diseases. Moreover, in low and medium U5MR groups, three-quarter of countries have over 90% immunization rate of DPT and measles. However, there are only about a quarter of high U5MR countries that have over 90% immunization rate of DPT and measles. Therefore, the countries with lower child mortality rate do make more efforts on health care and child immunization. Also, for high U5MR group, the correlation coefficients between U5MR and immunization rate, DPT and between U5MR and immunization rate, measles are both negative ($r=-0.459$ and $r=-0.371$, respectively), indicating that promoting immunizations can help high U5MR countries reduce child mortality rate.

		Min.	1st Qu.	median	3rd Qu.	Max.
low	DPT	76.00	94.00	96.00	98.00	99.00
	Measles	73.00	92.00	95.00	97.00	99.00
medium	DPT	52.00	90.00	95.50	98.75	99.00
	Measles	52.00	92.25	97.00	98.00	99.00
high	DPT	39.00	71.50	83.00	91.00	99.00
	Measles	46.00	68.75	79.00	92.25	99.00

Table2

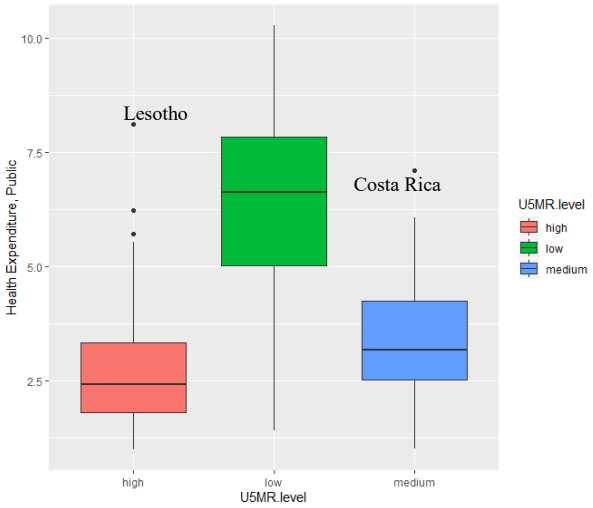

Figure5

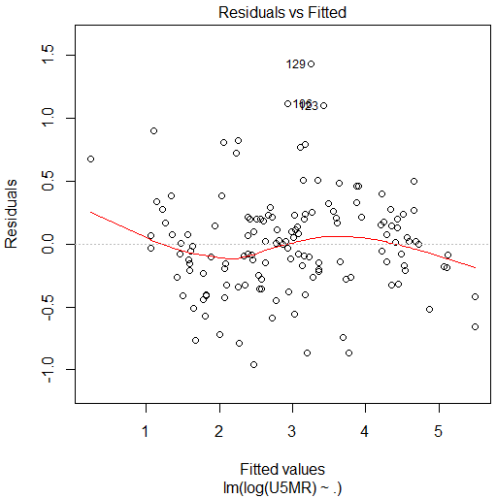

Figure 6

5 Regression

5.1Model fitting

After examining factors related to child mortality, a model to describe the relationship between child mortality and the factors are desired. Take U5MR as response, the predictor variables should include indicators of education, fertility, wealth and public health. Since the correlation of total fertility rate and adolescent fertility rate (r=0.828) and the correlation of immunization rates of DPT and measles (r=0.903) are strong, I used educational expenditure, total fertility rate, PPP, HEP, and DPT as predictor variables and did linear regression. This model can explain most of variability of

U5MR (R^2=0.848, R^2_{adj}=0.842). Unexpectedly, the results show that the variables "Educational expenditure" and HEP are not significant (t=0.391, p=0.696; t=-0.701, 0.485). Since education affects child mortality in a relatively indirect way, I fit the new model without educational expenditure and apply log transformation in U5MR. Now all predictor variables appear significant ($p<0.01$ for all variables), and this model explains variability better than the previous one (R^2=0.882, R^2_{adj}=0.879). The model is: $\log(U5MR)=3.553+3.715*10^{-1}$(Fertility Rate)$-3.617*10^{-5}(PPP)-8.094*10^{-2}(HEP)-9.392*10^{-3}$(DPT). Therefore, increasing people's wealth, public health inputs, and immunization rate and reducing fertility rate can help to reduce child mortality rate.

5.2 Diagnosis

Residual analysis reveals that Lesotho is an outlier (standardized residual =3.21). This is consistent with the findings in section 4. These findings suggest that fertility rate, PPP, HEP, and DPT are not enough to explain high child mortality rate in Lesotho. Since it has the second highest HIV prevalence in the world, it is necessary to identify if HIV is the leading cause of child mortality in Lesotho [11]. If so, to reduce child mortality, Lesotho should take more effort to protect children from HIV, for example, prevent mother-to-child HIV transmission. Hence, we should keep the data of Lesotho in regression since it gives us important information about child mortality.

In addition, the residuals seem to violate the linearity assumption of model (Figure 6), indicating that a linear model is not the best for describing the data. The model can be improved in further study by using other methods.

6 Conclusions

This study reveals the geographic patterns of under-5-year child mortality and finds some key factors that relates to child mortality rate. The mortality rate varies much among regions: It is low in most of Europe and Central Asia and North America

countries, while it is high in most of Sub-Saharan countries. Furthermore, education, fertility rate, economy status, public health expenditure and child immunization can influence the child mortality rate in a country. Generally speaking, higher education expenditure, higher GDP per capita, higher public health expenditure, more immunizations of DPT and measles and lower fertility contribute to a lower child mortality rate. In addition to qualitative analysis, this study also constructs a model to describe the relationships between child mortality rate and wealth, health expenditure, fertility rate, and immunization of DPT.

The Sustainable Development Goals (SDGs) adopted by the United Nations in 2015, and one of targets of SDG Goal 3 is to reduce under-five mortality to at least as low as 25 per 1,000 live births in every country by 2030 [13]. Since there are only 89 countries out of 143 studied countries meet this target by 2010, we are currently far away from reaching the global goal for child mortality. To promote child well-being, countries should develop economy to increase people's wealth, increase public health inputs, and promote child immunizations and control fertility rate to improve maternal health. Providing a basic education is also crucial to reduce child mortality, because universal basic education can reduce poverty, increase health workers and enhance people health consciousness [14].

6.1 Limitations

In this study, only the data in 2010 are used, so we cannot see how the child mortality changes over time. Also, some factors that can affect child mortality rate, such as pneumonia, are not being discussed in this report. As for the factors examined, this report does not justify the validities of used indicators and does not determine the casual relationships between child mortality and the factors. In the model in section 5, the magnitude of coefficients cannot reflect the extent that a factor influences child

mortality. Although the model in section 5 extracts most of variability of data, diagnosis results indicates that a linear model is not the best choice.

6.2 Recommendations

Since child mortality is a major concern globally, future researches in this domain would move to deeper levels. First, they can look at the data in different time and explore the mortality trends. Second, future researches can use different indicators to assess the discussed factors and give justifications for them. For instance, they can combine GDP and GDP per capita to assess the wealth. More factors related to mortality can be explored and the causal relationship can be examined in the future. Furthermore, future studies may use different methods to construct the models for child mortality. Hopefully, these researches will contribute to child survival and lead to a better future of world.

7 References

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