Modeling and Forecasting Infant Mortality Rates of Asian Countries in The Perspective of GDP(PPP)

Mehwish Shafi Khan, Samreen Fatima, Syeeda Sadia Zia, Ehtesham Hussain, Tayyab Raza Faraz, Farah Khalid

Abstract—In recent researches infant mortality has been considered as an important factor to gauge health of society in any country. Infant mortality is one of the vital indicators of social development along with other parameters such as: infant health, mother's health and education. Infant mortality rate depends on different factors like environment, socioeconomic conditions, geographic location, and certain demographics. Health is primary component which determines the monetary position of economic growth. In this study, we have compared infant mortality rate with GDP (PPP (Purchasing Power Parity)) of developed, underdeveloped and lower developing countries of Asia such as: Bangladesh(BA), China(CH), India(IN), Japan(JA), Sri Lanka(SL), Nepal(NE), Oman(OM), Pakistan(PK), Philippine(PH), Saudi Arabia(SA), Singapore(SP), Thailand(TH) and Turkey(TK). The empirical analysis shows there is a strong negative correlation between infant mortality rate and GDP (PPP). Generally, the lower developing countries have very high infant mortality rate and low per capita income as compared to developed countries and the state of affairs is bad for the countries with low GDP like Pakistan, Bangladesh, India and Nepal. Furthermore, we have also used log-log regression and coefficient of correlation to find the relationship between GDP (PPP) and infant mortality for each of the selected country. Secondary data of IMR and GDP(PPP) from 1980 to 2015 has been analyzed and forecast has been done from 2016 to 2025. AR (1) is found suitable for all the countries except Japan and Nepal for which ARIMA (1,1,1) model is appropriate based on FMSE and FRMSE.

Keywords— AR (1) model, ARIMA (1,1,1) model, Asian Countries, GDP (PPP) per capita, Infant mortality rates, Log-Log model

1. INTRODUCTION

Health is one of the major factors which examines the economic condition of a country. Infant mortality rate is an important indicator of a nation's health status because health is primary component which determines the monetary position of economic growth [1, 2].

After 1950's, various researches have been made in controlling health issues worldwide in order to reduce the trend of infant mortality and increase life expectancy and average lifespan and till today, science has been very much successful in controlling all issues [3-8].

Infant mortality rate is the ratio of deaths under one year of age in a given year to the overall quantity of live births within the same year; normally expressed as rate of deaths per a thousand live births. Its importance lies inside the fact that it's far a trademark of health reputation of not only infants but additionally entire population & socioeconomic situations. It is a sensitive indicator of availability, utilization & effectiveness of health care, especially perinatal care [9]. Infant mortality is correlated with a range of different factors like environment, socioeconomic conditions, geographic location, maternal health, and certain demographics [10-12].

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The level of socioeconomic development of the nation determines the variable effects of socioeconomic factors on infant mortality [13, 14]. Socioeconomically disadvantages are indirectly at higher risk for increased infant mortality via health resources [15, 16]. It shows how much the government spend on the health sector and the factors responsible for low development. Over the years with the passage of time, improved policies and regulations are introduced and refined for the betterment of the society considering mainly the health and education sectors. Most infant deaths of growing countries are avoidable and if occur that is because of the necessity of household resources, populace services and the lack of information. So, increase within the household (private) income may additionally be kept to enhance maternal and child nutrition [17].

Having discussed above factors, There is considerable role of information in the improvement of health by applying prevention and cure; and it seems that education makes parents more efficient at seeking and applying knowledge [18]. It is obvious that health expenditure and education is directly associated with private household income or GDP at Purchasing Power Parity (PPP) Therefore, we may expect that increase in private or public health expenditure increases health (or survival chances) to depend upon the level of education of the parents.

In this study, we selected infant mortality rate of developed, underdeveloped and developing countries of

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Asia to examine the health situation of these countries along with GDP (PPP) to examine the living standard of these countries.

In the Empirical analysis, we figure out that there is a strong negative correlation between infant mortality rate and GDP (PPP). Generally, the lower developing countries have very high infant mortality rate and low per capita income as compared to developed countries. As people of developed countries spend more on health which means that health expenditure of developed countries is also high. So we may expect that if the health expenditure of a country is high then there should be fewer chances of infant deaths.

We use different statistical processes such as simple regression, AR (1) and ARIMA (1, 1, 1) to model and forecast mortality rates of selected countries for the period 2016 to 2025.

The purpose of this paper is to determine the association between infant mortality and GDP (PPP) via simple regression and correlation. Also, we aim to forecast future infant mortality rate using time series models.

In section 2 we have shed some light on literature review. Section 3 describes the brief introduction of statistical techniques. The data analysis and results are presented in section 4. Whereas, section 5 consists of conclusion of the research.

2. Literature Review

GDP based on PPP per capita of a country is defined as how much of a local good (like real estate, labor, or locally grown produce) a person can buy in a country. The relationship between per capita income and overall child mortality (deaths all told children below the age of five) has been understood for several years [19]. A robust negative relationship between per capita income level (using per capita gross domestic product or gross national income: gross domestic product or gross national income per capita (GNI) and child mortality has been well documented in variety of studies and it can be easily examined that economic condition of a country could be a potential reason that why numerous children die before reaching the age of five [20-22] . Comprehensively, the infant mortality rate (IMR) is considered a more sensitive indicator of population health because it is about to focus the attention of health policy on a small part of the population [8]. In high –income countries the main causes of deaths in the period 1-4 years of age are mainly accidents and late effects of congenital disorders [23]. Hence, factors like the basic health service system, female education, safe drinking water, and nutrition have probably limited effect on an infant or under-five mortality in developed countries. On the other hand, these factors are main causes for developing countries or under developing countries [24]. Growth along with other factors discussed above of any country helps to reduce mortality. In [25] TK Chakrabarty investigated that how do Asian countries are contributing in reducing the infant mortality rate. TK Chakrabarty further discussed in results that there is a slow trend of IMR in entire region of South Asian countries, the average annual progress in reducing IMR in India. Whereas, Pakistan and Afghanistan is far better than other Asian countries, according to TK Chakrabarty [25]. Examining IMR along with factors discussed in introduction section is not an easy task. Whereas, experimental science provides amazing techniques to perform such examinations on IMR [26].

3. Data

In this study yearly secondary data of Infant Mortality rate (IMR) and GDP (PPP) (GDP based on per capita) from 1980 to 2015 acquired from World Bank official websites, www.worldbank.org has been used. We selected Asian countries namely: Bangladesh(BA), China(CH), India(IN), Japan(JA), Sri Lanka(SL), Nepal(NE), Oman(OM), Pakistan(PK), Philippine(PH), Saudi Arabia(SA), Singapore(SP) , Thailand(TH) and Turkey(TK) for modelling and forecasting of IMR.

4. Methodology

Data analysis using statistical tools is of common practice due to variety of methods and their flexibility to model the systems. In statistics, regression analysis is one of leading statistical technique which is use to inspect the relationship between two or more variables of interest.

There are many types of regression analysis such as Linear regression, Logistic regression, Ridge regression, Lasso regression, Ecologic regression, Logic regression, Bayesian regression, Quantile regression, LAD regression, Jackknife regression etc. Different statistical models are available being used in forecasting especially when using time series analysis. We discuss few models related to our methodology.

4.1. Log-log model

In time series modeling using natural logarithms of variables on both sides for specification is called a log-log model. This model is convenient when the relationship is nonlinear in parameters as the log transformation generates the desired linearity in parameters, because the linearity in parameters is one of the assumptions of Ordinary Least Squares.

We define Log-log model for IMR as follows:

$$\ln \mathrm{IMR} = a_t + b \ln Y_t + u_t \quad \ldots\ldots\ldots\ldots (1)$$

Where, IMR denote the infant mortality rate, Y_t denote GDP based on PPP per capita, parameter 'b' represents the elasticity (measure the percentage change in (IMR) with respect to GDP(PPP)). (1) includes constant effects, denoted as 'a'. Where ' u_t' is random error which follows white noise with mean zero and variance σ^2.

Parameters of (1) are estimated by the ordinary least squares (OLS) method.

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4.2. ARIMA MODEL

ARIMA model belongs to the class of linear statistical model used to analyze and forecast time series data [27]. ARIMA model is a generalization of Auto Regressive (AR) and Moving Average (MA) including the notion stationary (integration).

A moving average (MA) process is modest class of time series model. It consists of past error (v_t) multiplied by a constant (coefficients). Where v_t is a white noise error, $v_t \sim$ i.i.d $N(0, \sigma^2)$.

A simple 1st order MA process can be expressed as,

$$Y_t = c_0 + c_1 v_{t-1} + v_t$$

or

$$Y_t = c_0 + c_1 v_{t-1} + c_2 v_{t-2} + \cdots + c_q v_{t-q} + v_t$$

or

$$Y_t = c_0 + \sum_{i=1}^{Q} c_i v_{t-i} + v_t \quad \ldots\ldots\ldots\ldots (2)$$

(2) is moving average model of order 'Q'. It is basically a linear combination of past error processes such that Y_t depends on the current and previous values of past error terms. Where c_0 and c_i are the coefficients of MA (Q) and $v_{t-1}, v_{t-2}, \ldots\ldots, v_{t-i}$ are lagged values of error.

This is also known as autoregressive process AR(P) that is a process in which existing value of a variable is a linear combination of past values and an error term.

1st order Autoregressive model, denoted by AR (1) is expressed as,

$$Y_t = d_0 + d_1 Y_{t-1} + v_t$$

or

$$Y_t = d_0 + d_1 Y_{t-1} + d_2 Y_{t-2} + \cdots + d_q Y_{t-q} + v_t$$

or

$$Y_t = c_0 + \sum_{j=1}^{P} d_j Y_{t-j} + v_t \quad \ldots\ldots\ldots\ldots (3)$$

(3) is autoregressive model of order ' P '. d_0 and d_j are (AR) coefficients and Y_{t-j} lagged values of the series Y_t, $v_t \sim$ i.i.d $N(0, \sigma^2)$. Combining both MA (Q) and AR (P) an autoregressive moving average ARMA (P,Q) process is defined.

$$Y_t = c_0 + \sum_{j=1}^{P} d_j Y_{t-j} + \sum_{i=1}^{Q} c_i v_{t-i} + v_t$$

Stationary process is one of the key concepts of a time series, so taking difference to make stationary an ARMA(P,Q) process is called auto regressive integrated moving average and denoted by ARIMA(P,I,Q) .

Where ' I ' is order of differencing transforming the series into a stationary , P is the order of autoregressive process and Q represent moving average process order.

5. DATA ANALYSIS AND DISCUSSION

Statistical analysis on IMR for each country has been compiled in Table 1. it is found that Japan being the most developed country of Asia has lowest infant mortality rate as compared to other selected Asian countries. Japan has an infant mortality rate of 1.29 death for every 1,000 live births. Comparing Japan with countries like Pakistan, Bangladesh Nepal or India, it can be seen that Japan's infant mortality rate is very low.

Table 1(a): Descriptive statistics of Infant mortality rate (IMR)

Country	BA	CH	IN	JA	NP	OM
Mean	4.24	3.31	4.24	1.29	4.2	3.02
Median	4.28	3.53	4.28	1.31	4.22	2.84
MX	4.9	3.87	4.74	2	4.94	4.37
MN	3.42	2.22	3.63	0.69	3.38	2.29
SD	0.46	0.52	0.33	0.37	0.5	0.69
SK	-0.22	-0.77	-0.24	0.11	-0.09	0.54
KR	1.78	2.16	1.87	1.91	1.7	1.89
JB	2.55	4.64	2.26	1.85	2.59	3.58
Prob.	0.28	0.1	0.32	0.4	0.27	0.17
Range	1.48	1.65	1.11	1.31	1.56	2.08
CV	10.85	15.71	7.78	28.68	11.9	22.85

Table 1(b): Descriptive statistics of Infant mortality rate (IMR)

Country	PK	PH	SA	SP	SL	TH	TK
Mean	4.52	3.51	3.23	1.4	2.76	3.07	3.56
Median	4.53	3.45	3.07	1.31	2.75	3.06	3.62
MX	4.8	3.97	4.26	2.48	3.67	3.85	4.5
MN	4.19	3.1	2.53	0.74	2.13	2.35	2.45
SD	0.19	0.28	0.54	0.59	0.43	0.47	0.62
SK	-0.1	0.32	0.51	0.46	0.4	0.08	-0.2
KR	1.75	1.76	1.91	1.76	2.46	1.74	1.83
JB	2.42	2.93	3.32	3.56	1.4	2.42	2.3
Prob.	0.3	0.23	0.19	0.17	0.5	0.3	0.32
Range	0.61	0.87	1.73	1.74	1.54	1.5	2.05
CV	4.2	7.98	16.72	42.14	15.58	15.31	17.42

Note: MX, MN, SD, SK, KR , CV and JB are followed maximum, minimum, standard deviation, skewness, coefficient of variance kurtosis and Jarque–Bera test respectively.

Bangladesh(BA), China(CH), India(IN), Japan(JA), Sri Lanka(SL), Nepal(NE), Oman(OM), Pakistan(PK), Philippine(PH), Saudi Arabia(SA), Singapore(SP) , Thailand(TH) and Turkey(TK).

Furthermore, standard deviation (SD) is 0.69 (high), 0.19 (low) for Oman and Pakistan respectively. This suggests

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that Oman has high variability and Pakistan has low among all considered countries. Furthermore, coefficient of variance (CV) for PK i.e. 4.2 is very minimum indicating consistency in IMR.

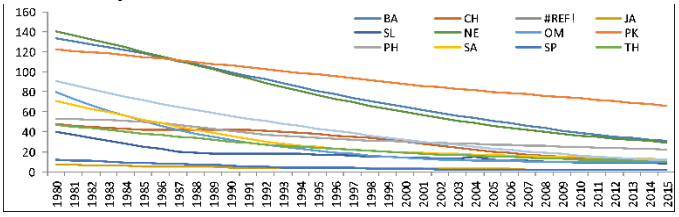

Figure 1: Trends in Infant Mortality against Time

Figure 1, shows that IMR of JA, OM and SA has parabolic decreasing trend. Whereas, NP and BA have exponential decreasing trend. On the other hand, PK depict linear decreasing trend. Moreover, PK takes place at the top represent high IMR whereas, JA occurs at the bottom shows low IMR. Generally, the least developing countries have very high infant mortality rate and low per capita income as compared to developed countries. In addition to this, state of affairs is bad for the poorer countries such as: Pakistan, Bangladesh, and Nepal.

Table 2(a): Descriptive statistics of GDP, PPP (GDP based on per capita)

Counytry	BA	CH	IN	JA	NP	OM	PK
Mean	7.16	7.74	7.51	10.04	6.97	10.2	7.79
Median	7.09	7.76	7.46	10.14	6.99	10.32	7.82
MX	8.2	9.57	8.73	10.6	7.81	10.75	8.5
MN	6.23	5.74	6.32	9.08	6	9.07	6.79
SD	0.57	1.15	0.7	0.43	0.51	0.46	0.48
SK	0.24	-0.04	0.13	-0.67	-0.09	-0.71	-0.31
KR	1.89	1.84	1.88	2.39	1.94	2.57	2.1
JB	2.19	2.03	1.97	3.25	1.73	3.32	1.79
Prob.	0.34	0.36	0.37	0.2	0.42	0.19	0.41
Range	1.97	3.83	2.41	1.52	1.81	1.68	1.71
CV	7.96	14.86	9.32	4.28	7.32	4.51	6.16

Table 2(b): Descriptive statistics of GDP, PPP (GDP based on per capita)

Counytry	PH	SA	SP	SL	TH	TK
Mean	8.12	10.48	10.4	8.23	8.73	9.18
Median	8.05	10.44	10.49	8.3	8.86	9.2
MX	8.89	10.91	11.36	9.37	9.69	10.1
MN	7.54	10.03	9.09	7.03	7.38	8.2
SD	0.39	0.23	0.67	0.67	0.7	0.53
SK	0.41	0	-0.31	0.01	-0.43	-0.04
KR	2	2.28	1.95	1.9	1.99	2.06
JB	2.53	0.77	2.23	1.8	2.65	1.33
Prob.	0.28	0.68	0.33	0.41	0.27	0.51
Range	1.35	0.88	2.27	2.34	2.31	1.9
CV	4.8	2.19	6.44	8.14	8.02	5.77

Table 2 shows that SA holds highest average and NP has lowest average GDP (PPP) value. Furthermore, the countries which have highest i.e. above 10 average GDP (PPP) are: SA (10.48) >SP (10.4) >OM (10.2) >JA (10.04). From Table 1, JP and SP have lowest IMR i.e. less than 2, but SA and OM have greater than 3 IMR. This result indicates that there is a negative relation between IMR and GDP (PPP) for JA and SP. Comparing CV, SD and range of the countries it is found that SA and CH follow minimum and maximum values of GDP(PPP) respectively. This demonstrates IMR is less consist in CH than SA.

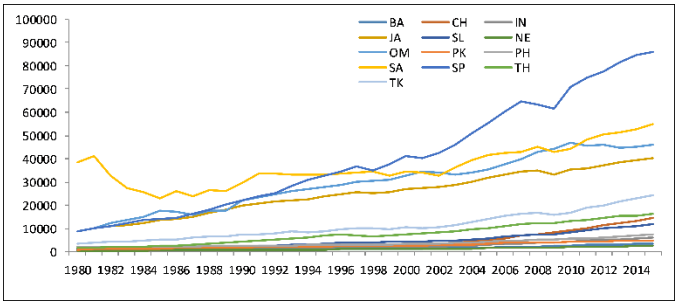

Figure 2: Trends in GDP (PPP) against Time

Figure 2, shows comparison between the Infant mortality rates of selected Asian countries for every 1,000 live births and GDP per capita. It can be seen in figure 2 that GDP (PPP) of all the countries rests at the bottom except that of SP, SA, JP and OM. Comparing Figure 1 & Figure 2 there is a visible decline in IMR and growth in GDP (PPP) in the selected countries of Asia. In Figure 2 there is a visible growth in all over the region of Asia in GDP (PPP). Whereas, In Figure 1, increasing trend can be seen 2010 onwards in IMR of Singapore and Japan as compared to other developing countries.

We further investigate the relationship between the variables using log-log regression model. The dependent variable is " IMR " and the GDP(PPP) is considered as independent variable.

Table 3: Regression and Correlation Analysis

Country	REGRESSION EQUATION	R-Sq.	Correlation
BA	log(IMR) = 10.0 - 0.806 log(GDP, PPP)	99.70%	-0.998
CH	log(IMR) = 6.59 - 0.425 log(GDP,PPP)	88.00%	-0.938
IN	log(IMR) = 10.0 - 0.806 log(GDP, PPP)	99.70%	-0.998
JA	log(IMR) = 6.59 - 0.425 log(GDP,PPP)	88.00%	-0.973
SL	log(IMR) = 10.0 - 0.806 log(GDP, PPP)	99.70%	-0.975
NE	log(IMR) = 6.59 - 0.425 log(GDP,PPP)	88.00%	-0.994
OM	log(IMR) = 10.0 - 0.806 log(GDP, PPP)	99.70%	-0.982
PK	log(IMR) = 6.59 - 0.425 log(GDP,PPP)	88.00%	-0.983
PH	log(IMR) = 10.0 - 0.806 log(GDP, PPP)	99.70%	-0.951
SA	log(IMR) = 6.59 - 0.425 log(GDP,PPP)	88.00%	-0.731
SP	log(IMR) = 10.0 - 0.806 log(GDP, PPP)	99.70%	-0.985
TH	log(IMR) = 6.59 - 0.425 log(GDP,PPP)	88.00%	-0.987
TK	log(IMR) = 10.0 - 0.806 log(GDP, PPP)	99.70%	-0.989

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Table 3 shows that Pearson correlation coefficient between GDP (PPP) and infant mortality rate (IMR) is close to -1 for most of the countries which is high except for SA i.e. -0.731. This indicates that there is a very strong negative relationship between infant mortality and GDP(PPP). The model obtained from regression analysis also suggested that with increase in GDP the IMR is decreased. It is observed that BA, IN, SL, OM, PH, SP and TK have same coefficient (-0.806). Therefore, 1% increase in GDP (PPP) will generate -0.806% decrease in IMR. Similarly, remaining countries display that 1% increase in GDP(PPP) will generate decrease of about 0.425% in IMR. The coefficient of determination for each country is greater than 0.88 which explains approximately 90% variation in IMR due to GDP (PPP).

6. Forecast

To forecast future infant mortality rate ARIMA model is applied on stationary data using data from 1980 to 2010 and from 2011 to 2015 is used as out sample forecast. The following models are found most suitable on the bases of Akaike info Criterion (AIC) and Schwarz Criterion (BIC). All the parameters of the suitable models are significant at 5% level of significance.

Table 4: output of ARIMA model

Country	Models	Variable	Coefficient	Std. Error	t-Statistic	Prob.
BA	AR(1)	C	-0.05	0	-10.62	0
		AR(1)	0.9	0.04	21.06	0
CH	AR(1)	C	-0.09	0.11	-0.81	0.421
		AR(1)	0.98	0.04	27.88	0
IN	AR(1)	C	-0.04	0.01	-2.84	0.008
		AR(1)	0.97	0.04	21.96	0
JA	ARIMA(1,1,1)	C	-0.04	0	-8.02	0
		AR(1)	0.77	0.05	16.4	0
		MA(1)	-1.42	0.22	-6.54	0
NE	ARIMA(1,1,1)	C	-0.03	0	-13.69	0
		AR(1)	0.73	0.13	5.47	0
		MA(1)	-1	0.18	-5.69	0
OM	AR(1)	C	-0.05	0	-13.31	0
		AR(1)	0.91	0.04	20.21	0
PK	AR(1)	C	-0.33	0.95	-0.35	0.731
		AR(1)	1.01	0.03	34.11	0
PH	AR(1)	C	-0.03	0.01	-2.57	0.015
		AR(1)	0.95	0.06	16.75	0
SA	AR(1)	C	-0.03	0.01	-4.19	0
		AR(1)	0.91	0.05	16.95	0
SP	AR(1)	C	-0.02	0.07	-0.25	0.807
		AR(1)	0.98	0.05	21.44	0
SL	AR(1)	C	-0.05	0.01	-3.68	0.001
		AR(1)	0.64	0.14	4.74	0
TH	AR(1)	C	-0.04	0	-17.3	0
		AR(1)	0.72	0.13	5.75	0
TK	AR(1)	C	-0.06	0.01	-10.23	0
		AR(1)	0.91	0.05	16.52	0

Form time series models we have predicted 10 years IMR i.e. up to 2025 and the results are shown below in figure 3.

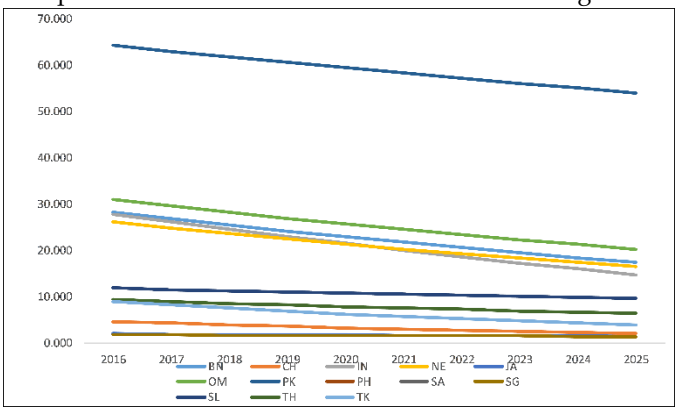

Figure 3: IMR Forecast of Asian countries from 2016 to 2025

Figure 3 represents forecasted IMR for each country. Decreasing trend in each of the country's IMR can be seen. To check the accuracy and validity of the models out-sample mean square errors (FMSE) and root means square errors (FMSE) are computed in Table 5.

Table 5: FMSE and FRMSE of forecasted model

Country	BN	CH	IN	JA	NE	OM	PK	SA	SG	SL	TH	TK
FMSE	1.01	3.22	0.91	0	0.23	14.7	2.8	4.39	1.38	6.53	0.04	0.17
FRMSE	1	1.8	0.95	0.05	0.48	3.83	1.67	2.09	1.18	2.56	0.21	0.41

It is observed that proposed models for each country provide suitable results based on forecast mean square error except for Oman and Sri Lanka.

7. Conclusion

The study focuses on total thirteen; developed, under developed and least developed countries of Asia mentioned above in the abstract. We discussed role of various factors in growth of infant mortality rate such as: health, education, socioeconomic developments and GDP(PPP). Thru literature it was found that GDP has more impact on IMR as compared to other factors. Therefore, we further enquired the relationship between IMR and GDP using statistical analysis. It is found that there is a strong negative correlation between IMR and GDP as per log-log regression model. Forecasting of IMR for each country was done using Time series ARIMA model. It was found that AR(1) model is suitable for all countries except Japan. Whereas, for Japan ARIMA(1,1,1) model is obtained. It is found that overall situation of IMR has improved. But, Pakistan maintains its position on the top of the list of all the selected countries having increased IMR which is an alarming situation. Whereas, China and Singapore are in better position with minimum IMR. On the other hand, Nepal, Japan and India fall in moderate category. The

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situation may be improved if GDP of these countries is increased.

8. RECOMMENDATIONS

Analyses show that GDP is increasing for all the countries considered in the study. But Pakistan is in alarming situation as compared to other countries. Although GDP(PPP) of Pakistan is increasing but IMR is also increasing in contrast to strong negative correlation. Which is an indicator for Pakistan that other factors especially health and education should also be incorporated to design better model. Decision makers should opt well planned policies for health and education that may help Pakistan in reducing IMR in future. Furthermore, underdeveloped countries should compare their health and education policies with developed one in order to improve their planning.

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