Determinants of Infant Mortality Rate: A Cross National Study

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Abstract
Infant mortality rate (IMR) is often considered a better indicator of the overall success of a nation than gross domestic product (GDP) or other leading economic indicators. This study analyzes the relationships between lead economic and health indicators and IMR in developed and developing countries. The analysis uses 2005, 2009, and 2012 panel data from the World Bank and the United Nations Human Development Report. Panel data models are estimated for all countries, only developed countries, and only developing countries to identify the effect of key explanatory variables on IMR and differences over time between developed and developing countries.

I. Background and Motivation

This paper will focus mainly on Infant mortality rate (IMR). IMR is often regarded as being a better indicator of the overall success of a nation than gross domestic product (GDP) or other economic indicators; it serves as an indicator of the overall health of a population. IMR is a giant concern for many developing countries where there is limited access to health care and suitable living conditions. In developed countries IMR is less of a problem, however it is important to note that the United States has the highest IMR among the OECD countries (Chen & Williams, 2013). It is known the most common causes of infant and child deaths worldwide is dehydration due to illness, lack of immunizations, and poor sanitation (Gordon, 2009), however there is a lack of research on the socioeconomic factors affecting IMR.

In 2000 the United Nations developed eight international development goals following the millennium summit, each goal was to be achieved by the year 2015. Goal four was to reduce child mortality rate and IMR rate by two-thirds. Since the summit, the number of deaths in children under five worldwide declined from 12.7 million in 1990 to 6.3 million in 2013. However, an increasing proportion of child deaths are in Southern Asia and sub-Saharan Africa. The UN found that as overall CMR declines, the proportion of deaths that occur during the first month after birth is increasing, children born into poverty are almost twice as likely to die before the age of five as those from wealthier families, and children with educated mothers are more likely to survive than children of mothers with no education (United Nations).

While IMR is defined as deaths in infants less than one year of age per 1,000 live births, there are a few limitations to any study using IMR data because of the differences in reporting between countries (Ingraham, 2014). Some countries include all live births in IMR, while others only include live births at 22 weeks gestation or more and/or 500 grams of birth weight or more.

Also extremely preterm births recorded in some places may be considered a stillbirth or a miscarriage in other countries and not be included in IMR calculations (Ingraham, 2014). Therefore, IMR may be overstated in countries where advanced healthcare practices allow preterm infants or infants with certain aliments to be born alive, mainly wealthy countries (Chen & Williams, 2013).

The United States has the highest healthcare spending levels in the world but has one of the highest IMR among developed countries at 5.9 deaths per 1,000 live births in 2013 (Ingraham, 2014). There is considerable state level variation. When looking at individual state's IMR, Mississippi with 9.6 deaths per 1,000 live births, would fall between Botswana and Bahrain (Ingraham, 2013). Chen, Oster, & Williams found that 40% of the United States disadvantage can be attributed to preterm births, but the other 60% remains a problem. The infant mortality gap grows as babies age, there is a high mortality among less advantaged groups (Chen & Williams, 2013); poor babies are less likely to survive because of the lack of access to quality healthcare (Chen & Williams, 2013).

II. Research Question

My thesis paper will seek to analyze correlations between lead economic and health indicators and IMR in developed and developing countries. I will conduct a quantitative analysis that will answer these research questions: **Do the socioeconomic determinates of IMR vary between developed and developing countries? Why is the United States rate higher than that of other developed countries?** The analysis will be conducted using country data from 2005, 2009, and 2012 from a sample of developed and developing countries.

III. Literature Review

There is much literature available regarding the socioeconomic factors associated with IMR in developed countries, developing countries, and the United States specifically. Schell et al. (2007) used IMR at country level to assess the importance of major socioeconomic determinants of population health. The paper stated that even though major causes of infant and child death are known and easily identified, knowledge of the underlying socioeconomic determinants of IMR is lacking (Schell et al., 2007). Countries were used as units of observation. The study used five predictors: public spending on health (in 2003 USD per capita), Gross national income (GNI) per capita (in 2003 USD), poverty rate (proportion of the population living on less than $1USD per day), income inequality (Gini index), and young female literacy rate (percentage of females 15-24 who are illiterate), based on existing literature. All the data was collected from "World Development Indicators 2003," 56 of 208 countries were excluded because of incomplete data (Schell et al., 2007). Most of the data, except female illiteracy, came from 2003 world development indicators; female literacy data was from UNESCO. The data were analyzed using univariate and multivariate regression, and also stratified for low, middle, and high-income countries using World Bank cutoffs for GNI (Schell et al., 2007). It was found that IMR was strongly and negatively correlated with public spending ($r = -.87$) and GNI/capita ($r = -.91$) in univariate regression, but not as strongly associated when using multivariate regression. Public spending on health and poverty rate were found to be insignificant. Female illiteracy was more important than GNI/capita in low-income countries, while income inequality was an independent predictor of IMR in middle-income countries only. GNI/capita, young female illiteracy, and income equality predicted 92% of the variation in national IMR (Schell et al., 2007). Schell et al. concluded that the importance of major health determinants varies between income levels and functioning health systems are necessary to make health investments efficient.

Looking at the United States specifically, the study conducted by MacDorman & Mathews (2008) looked at recent trends in IMR in the United States. The United States IMR declined throughout the 20th century but has reached a plateau since (MacDorman & Mathews, 2008). United States IMR was 6.89 per 1,000 live births in 2000 and 6.86 per 1,000 live births in 2005, showing an insignificant difference (MacDorman & Mathews, 2008). Additionally, the United States ranked 12th in worldwide IMR in1960 and fell to 29th by 2005 (MacDorman & Mathews, 2008). The study found that the United States IMR is associated with a variety of factors including access to medical care, socioeconomic conditions, and public health practices (MacDorman & Mathews, 2008). Using data from the National Vital Statistics System, MacDorman & Mathews also studied racial and ethnic differences in IMR. As 2005 the IMR for non-Hispanic Black American women was 13.63 and the IMR for non-Hispanic White American women was 5.7 (MacDorman & Mathews, 2008). The racial and ethnic differences were unexplained by the study. Another major factor the study focused on was pre-term birth. Pre-term birth in the United States increased from 11.6% of live births in 2005 to 12.7% in 2006, an increase of .9%. 68.6% of infant deaths occurred in preterm infants in 2005, and IMR for very premature infants (less than 32 weeks gestation) was 180.94 per 1,000 in 2000 and 183.24 per 1,000 in 2005; which is intriguing because the rate was not significantly changed, but it did increase instead of decrease. It was concluded that the increase in pre-term births accounted for the United States poor performance in reducing IMR (MacDorman & Mathews, 2008). However, the study did not compare increases in per-term birth in the United States with pre-term birth rates in other countries. Therefore, the data seems inconclusive when trying to identify why the United States has a higher IMR than other similarly developed countries.

There is also literature available on studies conducted to identify factors associated with trends in infant and child mortality in developing countries. One study by Rutstein (2000) used survey data (89 surveys from 56 countries) from the Demographic and Health Survey Programme. The study focused on the notion that while IMR and CMR in the 1990's declined in most countries, IMR increased in some developing nations. The study identified several groups of factors associated with IMR and CMR: fertility behavior, nutritional status of children and patterns of infant feeding, maternal and child health status, use of health services, environmental health factors, and socioeconomic factors (Rutstein, 2000). All data used was collected from Demographic and Health Survey Programme, 86 surveys from 56 countries in the years 1986-1998 were used. The two most significant factors identified by Rutstein, that are responsible for declines in IMR and CMR are better living conditions (access to better food and clean water, also more sanitation) and access to health care (women receiving prenatal care and births assisted by professionals). IMR in developing countries was also analyzed in a study by Gordon (2009) analyzed IMR and CMR in Haiti. The study argues that infant mortality is the most sensitive indicator of a child's health and serves as a measure of the effectiveness of public sector policy in addressing the needs of a nation's poor and disadvantaged (Gordon, 2009). There are many factors that impact IMR and CMR; mainly poverty, which usually results in young mothers living in unsanitary conditions and location, which can result in healthcare facilities being far away and inaccessible without transportation (Gordon, 2009). Wood and Lovell (1992) found that public health services, health and environmental services that reduce cost of healthcare but require some individual response, and individual characteristics (income and education) influence level of childhood mortality. This study used maternal education and proxy income (none or some) as socioeconomic factors, residence (rural or urban) and age as demographic factors, and piped water (yes or no) and toilet (yes or no) as health related factors. All data was taken from the 2000 Haiti demographic Health and Survey. When using incremental analysis on education, the study found that education was statistically significant in reducing the likelihood of childhood mortality by 20.8%. Also that incremental analysis on income showed that income could reduce childhood mortality by 20.8% (Gordon, 2009).

IV. Data and Methods

In order to effectively answer my research questions, I will run three separate regressions. One regression will be an ordinary least squares (OLS) regression that includes all of the countries used in my analysis, the other will be a fixed effects panel model that includes only developed countries, and the last will be a fixed effect panel model that includes only developing counties. In the OLS model IMR will function as the dependent variable while development status, year, GDP per capita, health expenditure per capita, population density, incidence of tuberculosis (TB) per 100,000, expected years of schooling for females, and unemployment rate will function as independent variables. The panel models will not include a variable for development status or a variable for year. The data used in this study was collected from The World Bank database with the exception of expected years of schooling for females, which was collected from the United Nations Development Programme (UNDP) Human Development Report. A summary of variables and their descriptions can be found in Table 1. The hypothesized OLS model is $IMR = \beta_0 + dev - \log(gdp) – \log(he) - pop - edu + tb - une + error$.

The hypothesized panel model for both classes of countries is $IMR_{it} = \beta_{0it} - \log(gdp)_{it} - \log(he)_{it} - pop_{it} - edu_{it} + tb_{it} - une_{it} + error$.

Table 1: Variables and Descriptions

	Variable	Description
IMR	Infant Mortality Rate	number of infants dying before one year of age per 1,000 live births in a given year
CMR	Under Five (Child) Mortality Rate	probability per 1,000 that a newborn baby will die before the age of five
GDP	Gross Domestic Product per Capita	gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidiaries not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. The data is in current US dollars.
HE	Health Expenditure per Capita	calculated using total health expenditure as the sum of public and private health expenditures as a ratio of total population. It covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation. The data are in current U.S. dollars.
POP	Population Density	midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.
UNE	Unemployment Rate	share of the labor force that is without work but available for and seeking employment
TB	Incidence of Tuberculosis per 100,000	estimated number of new pulmonary, smear positive, and extra-pulmonary tuberculosis cases
EDU*	Expected Years of Schooling for Females	number of years of schooling that a child of school entrance age can expect to receive if prevailing patterns of age-specific enrolment rates persist throughout life disaggregated by sex

***data from UNDP Human Development Report**

Table 2 provides summary statistics for independent variable calculated with the whole sample.

Table 3 provides summary statistics for developing and developed countries respectively.

Table 2: Summary statistics for each independent variable using data from the whole sample

Variable	N	Mean	Std Dev	Minimum	Maximum
imr	240	22.65	24.07	1.70	100.70
gdp	240	15953.71	19051.46	162.81	99635.87
he	240	1417.78	2002.79	6.63	9055.35
pop	240	126.93	211.22	1.62	1310.80
edu	240	13.63	3.62	3.10	20.80
tb	240	83.68	101.91	3.60	551.00
une	240	8.07	4.62	0.70	32.10

Table 3: Summary statistics for each independent variable using data from only developed countries (0) and only developing countries (1)

dev	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum

dev	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
0	102	imr	102	5.65	3.60	1.70	18.90
		gdp	102	27556.24	19697.42	797.20	99635.87
		he	102	2790.30	2256.95	75.97	9055.35
		pop	102	146.34	227.36	2.65	1310.80
		edu	102	16.35	1.77	12.10	20.80
		tb	102	30.79	40.93	3.60	176.00
		une	102	8.36	4.24	2.60	25.20
1	138	imr	138	35.22	25.03	2.90	100.70
		gdp	138	7377.92	13147.11	162.81	83295.26
		he	138	403.31	896.14	6.63	6464.05
		pop	138	112.58	198.07	1.63	1188.41
		edu	138	11.61	3.32	3.10	17.60
		tb	138	122.78	115.15	5.80	551.00
		une	138	7.85	4.90	0.70	32.10

V. Results

The first regression run was an OLS regression using all the data with dummy variables for development status and year. Results of this regression can be found in Table 4 below.

Table 4: Parameter estimates for OLS regression on all data

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
dev	1	10.89587	2.72353	4.00	<.0001***
t1	1	2.14256	2.30727	0.93	0.3541
t2	1	0.67929	2.26149	0.30	0.7642
loggdp	1	-1.10479	1.23903	-0.89	0.3735
loghe	1	2.42360	1.58904	1.53	0.1286
pop	1	-0.00795	0.00448	-1.78	0.0772*
edu	1	-3.09213	0.53222	-5.81	<.0001***

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
tb	**1**	0.08706	0.01485	5.86	<.0001***
une	**1**	0.06193	0.20848	0.30	0.7667

Statistical significance denoted using asterisks: *P < 0.10, **P < 0.05, ***P < 0.01.

The regression had an R^2 value of .66 which show a relatively weak relationship between IMR and the independent variables. As shown above, when using an OLS model only the parameter estimates for development status, population density, mean years of schooling for females, and incidence of TB per 100,000 were significant at least at the 10% level. The variable for development status behaved as expected, if a country is classified as developing, it would have a higher IMR. gdp and edu also behaved as expected with both being negatively correlated with IMR. Pop, tb, une, and he behaved differently than expected, possible reasons for that will be explored with further analysis.

Another OLS regression was then run with an interaction variable for development status with the independent variables gdp, he, pop, edu, tb, and une. Table 5 shows the results of this regression.

Table 5: Parameter estimates for OLS regression with interaction variables

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
dev	**1**	64.46962	33.98620	1.90	0.0591*
t1	**1**	2.25897	2.32364	0.97	0.3320
t2	**1**	0.67686	2.22016	0.30	0.7607
loggdp	**1**	0.70934	2.16259	0.33	0.7432
loghe	**1**	-0.49913	2.63714	-0.19	0.8501
pop	**1**	0.00031702	0.00700	0.05	0.9639
edu	**1**	-0.22212	1.06502	-0.21	0.8350
tb	**1**	0.07445	0.07370	1.01	0.3135

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
une	**1**	0.08672	0.43332	0.20	0.8416
dev_loggdp	**1**	-3.62234	2.68257	-1.35	0.1783
dev_loghe	**1**	5.46527	3.40492	1.61	0.1099
dev_pop	**1**	-0.00878	0.00932	-0.94	0.3470
dev_tb	**1**	0.01715	0.07512	0.23	0.8197
dev_une	**1**	0.06258	0.50459	0.12	0.9014
dev_edu	**1**	-3.64866	1.26405	-2.89	0.0043*

Statistical significance denoted using asterisks: *P < 0.10, **P < 0.05, ***P < 0.01.

This regression had a slightly higher R-squared value of .68. However, with this regression only dev and the interaction variable for dev and edu were significant at the 10% level.

To look at the United States specifically, a dummy was added for us (1 if United States, 0 for all other developed countries) and an OLS regression was run using data from developed countries only. The results of this regression can be found in Table 6.

Table 6: Parameter estimates for OLS regression on developed countries with United States dummy

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	**1**	8.93626	3.59314	2.49	0.0147
t1	**1**	1.02731	0.37589	2.73	0.0075**
t2	**1**	0.44661	0.34735	1.29	0.2017
us	**1**	3.79023	0.88538	4.28	<.0001***
loggdp	**1**	0.51076	0.22323	2.29	0.0244**
loghe	**1**	-1.06353	0.28574	-3.72	0.0003***
pop	**1**	0.00046098	0.00071904	0.64	0.5230
edu	**1**	-0.18344	0.10914	-1.68	0.0962*
tb	**1**	0.06221	0.00781	7.97	<.0001***
une	**1**	0.01046	0.04631	0.23	0.8218

Statistical significance denoted using asterisks: *P < 0.10, **P < 0.05, ***P < 0.01.

This regression has an R-squared value of .85 which shows a moderately strong association between IMR and the independent variables. This regression shows that IMR for the United States is 3.79 units higher than IMR in other developed countries Most of the parameter estimates were as expected except for gdp which has a positive association with IMR and is significant at the 5% level. There are a few possible explanations for this which will be exploded in the next section.

A fixed one-way panel analysis was then used for developed and developing countries, respectively. Tables 6 shows the F-test for no fixed effects and the Hausman test for the developed countries panel analysis.

Table 7: F-test for no fixed effects and Hausman test

F Test for No Fixed Effects			
Num DF	**Den DF**	**F Value**	**Pr > F**
33	62	21.32	<.0001***

Hausman Test for Random Effects		
DF	**m Value**	**Pr > m**
5	43.37	<.0001***

*****Significant at .01 level**

Hausman test is a test of H_0: random effects would be consistent and efficient, versus H_1: that random effects would be inconsistent. The m value was 43.37 and the p value was <.0001, therefore we reject the null hypothesis, that random effect would be a good model. The F-test for no fixed effects, testing the null that there are no fixed effects, rejected the null hypothesis with a F-value of 21.32 and a p value<.0001. Therefore the fixed effects model is appropriate. This means that the explanatory variables do not arise from random causes, there are time depend effects for each variable. The parameter estimates for the fixed effects model are shown in table 7.

Table 8: Parameter estimates for panel analysis of developed countries

Variable	DF	Estimate	Standard Error	t Value	Pr > |t|	Label
Intercept	1	32.62264	4.8418	6.74	<.0001	Intercept
loggdp	1	-1.19988	0.6168	-1.95	0.0563*	
loghe	1	-1.24778	0.5086	-2.45	0.0170*	
pop	1	-0.00421	0.0144	-0.29	0.7709	
edu	1	-0.13186	0.1803	-0.73	0.4672	
tb	1	0.077199	0.0135	5.72	<.0001***	
une	1	-0.00554	0.0295	-0.19	0.8518	

Statistical significance denoted using asterisks: *P < 0.10, **P < 0.05, ***P < 0.01.

The R-squared value for this analysis is .98 which suggests that this is a strong model. Gdp, he, and tb were significant at the 10% level. Gdp, he, pop, edu, and une all had negative relationships with IMR. The variables une and pop behaved differently than expected; possible explanations for this will be discussed in the next section.

A fixed one-way panel analysis was then run on data from developing countries only. Table 8 shows the results of the F-test for no fixed effects and the Hausman test for this data. A fixed effects model was shown to be the appropriate model. Table 9 shows the parameter estimates for this model.

Table 9: F-test for no fixed effects and Hausman test

F Test for No Fixed Effects			
Num DF	**Den DF**	**F Value**	**Pr > F**
45	86	95.45	<.0001***

Hausman Test for Random Effects		
DF	**m Value**	**Pr > m**
6	4.59	0.5975

*****Significant at .01 level**

Table 10: Parameter estimates for panel analysis of developing countries

Variable	DF	Estimate	Standard Error	t Value	Pr > |t|	Label
Intercept	1	103.6499	13.7267	7.55	<.0001	Intercept
loggdp	1	-5.50154	2.9282	-1.88	0.0637*	
loghe	1	-0.33024	2.3603	-0.14	0.8891	
pop	1	-0.07287	0.0397	-1.83	0.0700*	
edu	1	-1.70114	0.5080	-3.35	0.0012**	
tb	1	0.068456	0.0215	3.19	0.0020**	
une	1	-0.47473	0.2924	-1.62	0.1082	

The R-squared value for this analysis is .99 which suggests a strong association between IMR and the independent variables. Gdp, pop, edu, and tb were shown to be significant at the 10% level, with edu and tb being significant at the 5% level. All of the independent variables behaved as expected, except for pop.

Overall, determinants of IMR vary between developed and developing countries. In both cases gdp and tb were significant independent variables; however the negative effect of gdp in developing countries was about four times higher than the effect in developed countries. tb had a positive association with IMR in developed and developing countries which was expected and the parameter estimates were about the same for both country classes. The only other significant independent variable for developed countries was he, which was not significant for developing countries. In developing countries pop and edu were significant but pop has a negative association with IMR which was not expected.

VI. Conclusion

As the results indicate, the determinants of IMR do vary between developed and developing countries. In the case of developing countries GDP per capita, population density, expected years of education for females, and incidence of Tuberculosis per 100,000 were determined to be significant determinants of IMR. In developed countries GDP per capita, health expenditures per capita, and incidence of Tuberculosis per 100,000 were statistically significant indicators. This agrees with the common findings in the literature that economic indicators (GDP per capita and health expenditures per capita) are determinants of IMR.

It is interesting to note that the sign on population density and unemployment rate for both the developed and developing countries panel models were negative when they were expected to be positive. When looking more closely at the results the coefficient on population density from table 10 is very small (-0.073) and in the summary statistics for developing countries the standard deviation is very large (198.07). Delving deeper into the literature revealed mixed finding on the relationship between IMR and population density. Hathi et al. (2014) suggests that a high population density leads to poor sanitation which helps spread disease. However, population density for the purpose of this paper is a country average, it does not take into account urban and rural differences in population density, which could have potentially made the results more conclusive. Unemployment rate's negative association with IMR was also surprising, but in both panel analyses it was not statistically significant.

Table 6 shows that IMR in the United States is higher than that of other developed countries. However, the analysis does not reveal why. Literature suggests that reporting differences are partially responsible. Also pre-term births are responsible for most infant deaths in the United States, so it would be interesting to add a variable for pre-term birth to the analysis if that information were to become available.

If this study were to be replicated with a more complete data set, it would be advantageous to account for pre-term birth rates, births attended by professionals, percent of women receiving prenatal care, and vaccination rates. It would also be add to the quality of the results to adjust for inflation and account for the amount of aid received. This study also presents a few topics for further study. To take a closer look at the United States, one could replicated this study using state data instead of country data, and include a variable to account for racial and ethnic differences in IMR in the United States.

V. References

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