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The Asymmetrical Impact of Economic Growth on Infant Mortality in Developing Countries

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Abstract

This study investigates the effects of GDP per capita upon infant mortality using panel data from 83 developing countries over a period of 40 years. While economic growth broadly decreases infant mortality, the impact of economic growth upon infant mortality for the periods of economic booms and slumps is asymmetrical. Positive economic growth may have weak, mixed effects on infant mortality, but negative economic growth has a strong, adverse impact. The statistical evidence suggests that conflicting results in the literature regarding the impact of economic growth upon poverty alleviation can be explained by whether the concerned region and period experienced positive or negative economic growth.

JEL classification: O11, O47, I10

Key words: economic development, poverty, health, women's social status, panel data

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1. Introduction

Most people would agree that the problems of global poverty should be solved, but there has been little agreement as to how this should be achieved. A plausible, but conceivably the most controversial viewpoint is that increasing economic growth is a good policy for poverty reduction. The legitimacy of this viewpoint has been a persistent question over the last few decades, but the dispute seems far from being settled.[1]

Much regional evidence indicates that growth is ineffective in saving the poor. Krishna *et al.* (2005) report that the incidence of poverty did not change in a region of India during a period of fast economic growth. In their investigation of other regional evidence (Datt and Ravallion 2002 for India; Dercon 2006 for Ethiopia; Olavarria-Gambi 2003 for Chile) based on single country analysis, the authors express prudent, conditional reservations about the positive relationship between economic growth and poverty alleviation. Likewise, cross-country panel data analysis within Latin America by Janvry and Sadoulet (2000) finds a favorable growth impact upon poverty alleviation but only when initial inequality and poverty are sufficiently low. Furthermore, Easterly (1999) points out that the literature of economic history, a conventional form of which is single country analysis, provides ambivalent evidence.

In sharp contrast, an increasing body of empirical investigations with global data supports the view that growth is beneficial to the poor. Dollar and Kraay (2002), Ghura *et al.* (2002) and some other macro-economists argue that the aggregate growth of the entire economy raises the income of the poor.[2]

Another strand of research on the growth-poverty relationship sheds light on the status of

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[1] Such disagreement surfaced symbolically — though in a different, but closely related, context — in the conflict between globalization-skepticism in Stiglitz (2002) and pro-globalization advocacy in Bhagwati (2004), and in another recent controversy regarding the World Bank's Millennium Development Goals, that is, whether the number of poor people has been increasing or decreasing (Bhalla 2002; Chen and Ravallion 2004; Ravallion 2004; Sala-i-Martin 2002, 2006; World Bank 2000; among others).

[2] See Yamazaki (2007) for thought-provoking discussion on the Dollar-Kraay regressions.

health which is a direct measure of poverty, particularly if the objects of analysis reside in developing countries. The statistical relationship between health status (as a dependent variable) and GDP per capita (as an independent variable) is sought, and the estimated coefficient of GDP per capita is believed to "capture the private and public investments in nutrition inputs that are made possible by increased household and national income" (Smith and Haddad 2002, p.64). While use of a health variable as a proxy for the state of poverty in the context of the growth-poverty relationship is rare,[3] one of the few exceptions is an influential paper by Pritchett and Summers (1996). Using instrumental variable estimations and panel data for middle and low-income countries, they regressed infant mortality on GDP per capita and years of schooling and found that raising GDP per capita reduces infant mortality. Their empirical findings explicitly conclude that wealthier people are healthier. Subsequent empirical research supports the wealthier-healthier proposition (Fayissa and Gutema 2005; Filmer and Pritchett 1999; Haddad *et al.* 2003; Smith and Haddad 2002).

On the whole, the evidence available is both limited and mixed. Questions remain. The question of whether economic growth saves the poor is still unanswered. Arguably more important is why little consensus has been reached on this question in spite of an increasing body of research. For what reasons does the disagreement occur?

In order to address these questions, this study re-examines the relationship between economic growth and infant mortality with panel data from a maximum of 83 developing countries for the period 1962-2002. Changes in per capita GDP are divided into economic booms and slumps, and the asymmetrical effects of economic booms and slumps on changes in infant mortality are investigated.

The main conclusions of the study are two-fold. Firstly, on average, economic growth saves the poor. Increased per capita GDP decreases infant mortality in developing countries.

[3] See Deaton (2003) for an insightful survey with a broad perspective. Also see Smith and Haddad (2000) for a compact summary of past cross-country studies of child malnutrition.

Statistical procedures verify that this is a causal relationship from GDP per capita to infant mortality. Secondly, the impact upon infant mortality of income changes during the periods of economic booms and slumps is asymmetrical. Positive economic growth has weak, mixed effects on a reduction in infant mortality, but negative economic growth produces an adverse impact.

The remaining sections of the paper are organized as follows. Section 2 discusses the statistical methods and the data. Section 3 presents empirical results with a variety of econometric methods and model specifications with formal statistical tests. Section 4 offers some concluding remarks and further discussion.

2. Methods and Data

2.1. Methods

The present study is characterized by six aspects. First, following a paper by Pritchett and Summers (1996), log-linearity is assumed in the relationship between infant mortality and GDP per capita. This is reasonable because the present study investigates the panel data of developing countries only, where the achievable minimum infant mortality has not reached a rate at which the relationship can be considered as nonlinear.

Second, only developing countries are objects of analysis. Pritchett and Summers (1996) constructed their samples with middle and low-income countries defined as nations with a GDP per capita below $6,000. This caused their samples to include developed countries such as Greece. In contrast, the country samples of the present study are strictly composed of only developing countries, which are defined as Organization for Economic Cooperation and Development (OECD) non-member countries.

Third, gender-related aspects are discussed, the importance of which has often been emphasized. Recent empirical literature has highlighted some new determinants for health such as women’s social status, urbanization, and food availability. Re-examining the effects of these variables upon infant mortality is of great interest. Equally important, using these determinants as control variables helps to reduce the potential danger of omitted variable bias.

Fourth, two-way fixed and random effects linear regression models are utilized for precise estimation, in addition to the ordinary least squares (OLS) method. The two-way fixed effects model where the country-specific effects and the time-specific effects are considered is given by

$$H_{it} = \alpha_0 + \alpha_i + \delta_t + \beta y_{it} + \gamma' X_{it} + \varepsilon_{it} \,. \tag{1}$$

where H_{it} is the natural logarithm of infant mortality in country *i* in period *t*. It is assumed to be a linear function of a natural logarithm of per capita GDP (y_{it}), control variables (X_{it}), country-specific effects and time-specific effects. The $\alpha_i s$ are individual specific constants capturing country-specific effects, the $\delta_t s$ are time-specific constants, and the restrictions $\sum_i \alpha_i = \sum_t \delta_t = 0$ are imposed so that the problem of multicollinearity is avoided. The presence of country-specific effects allows for the presence of any number of unspecified country-specific, time-invariant variables that improve the level of infant mortality for any given level of per capita GDP.

The two-way random effects model is written as

$$H_{it} = \alpha + \beta y_{it} + \gamma' X_{it} + \varepsilon_{it} + u_i + w_t \,. \tag{2}$$

where u_i is the random disturbance characterizing the *i*th country and constant through time and w_t is the random disturbance characterizing the *t*th period and constant across countries.[4]

Fifth, potential problems of heterogeneity, endogeneity, omitted variables, and outliers are carefully handled. Heteroscedasticity is a common concern in cross-country and panel data analysis, while homoscedasticity is required to justify the orthodox *t*-tests and *F*-tests. It is well known that, provided the form of the variance as a function of explanatory variables is correctly specified, weighted least square (WLS) is more efficient than OLS. We therefore provide heteroscedasticity-robust statistics and implement WLS estimation.

Endogeneity is a serious concern in this research framework since per capita income may be endogenous of health-related variables such as infant mortality. If this is the case, the statistical

[4] For further discussion, see Greene (2008).

association between the variables might reflect reverse causality. Instrumental variables (IV) estimation is a useful approach to deal with the problems since the IV estimators mitigate these potential biases. We employ two-stage least squares (2SLS) estimation which incorporates multiple instrumental variables. The basic idea is that the explanatory variable of interest is regressed on instrumental variables to obtain its fitted value, and then the fitted value is used in the reduced regression. Instrumental variables must be uncorrelated with the error term and correlated with the endogenous explanatory variable (in this case, GDP per capita). Three instrumental variables employed here are the investment to GDP ratio (CI), openness to international trade (OPENC) and market distortions (PPPI). The first two variables are well-documented determinants of economic growth, and the last variable is a popular instrumental variable used in many empirical studies including Forbes (2000), which is usually proxied by the price level of investment. As these three variables are unlikely to influence health status, they are valid instrumental variables. Correlations between these instrumental variables are low: 0.337 between CI and OPENC; -0.146 between CI and PPPI; -0.026 between OPENC and PPPI. This indicates that each of the instrumental variables plays an independent role and provides different information.

Omitted variable bias is another serious concern if the error term contains an omitted variable which is correlated with per capita income. If such an equation is estimated by OLS, all of the estimators will be biased and inconsistent. In order to deal with the potential problem of the omitted variable bias, this study employs five-year first-difference estimation as well as the fixed effects model. To detect outliers, the Belsley-Kuh-Welsch (1980) method is implemented, details of which are discussed below.

Lastly, economic growth is partitioned into periods of booms and slumps. This is the main contribution of this study. A statistical relationship between economic growth and changes in infant mortality generally expresses only an average tendency. However, the impact of economic growth on changes in infant mortality during periods of economic booms may be different from the impact during periods of economic slumps. If this is the case, mixing up these different effects in averaging would at best yield a vague conclusion and at worst lead to incorrect policy-making. This is not a groundless supposition. In a slightly different context of adult mortality, Ruhm (2000) presented evidence using panel data for the USA that increased unemployment is associated with reduction in mortality, which suggests that a decreased income is associated with reduced mortality. His argument is that health status may improve during temporary economic downturns because economic decline decreases 1) the opportunity cost to undertake physical exercise and medical care; 2) risks from hazardous work conditions and stress from work; 3) drinking and driving; 4) crowding by migration flows. Provided that health does indeed improve during periods of economic slumps, then positive economic growth may have an adverse impact upon the health of a population. In the context of low-income countries, deterioration in adults' health causes the reallocation of scarce resources within a household at the expense of infants' health. If this is the case, then positive economic growth may or may not reduce infant mortality in developing countries.

In order to overcome this potential problem caused by mixing and averaging, income changes are partitioned into two types: income changes during periods of economic booms (that is, positive economic growth) and during periods of slumps (that is, negative economic growth). These separate effects are examined and estimated as follows:

$$\Delta H_{it} = \beta_1 \Delta y_{it} * pd_{it} + \beta_2 \Delta y_{it} * nd_{it} + \gamma' X_{it-1} + \varepsilon_{it} \qquad (3)$$

where $\Delta H_{it} = H_{it} - H_{it-1}$ and $\Delta y_{it} = y_{it} - y_{it-1}$ are imposed. The component *pd* is a 0-1 dummy variable for a positive economic change which scores one (zero otherwise) if country *i* experiences a positive economic change during the period between the years t and $t-1$. Likewise, *nd* is a 0-1 dummy variable for a negative economic change, and a country undergoing economic downturns during the period between the years t and $t-1$ scores one; otherwise, zero. If these estimated parameters are significantly different from each other, then this indicates that income changes affect mortality changes differently in periods of economic booms and slumps. This statistical procedure helps to reveal a new aspect of the growth-mortality relationship.

2.2. Data

Descriptive statistics are summarized in Table 1, and a detailed description of the data is provided in Appendix 1. The dataset consists of 83 developing countries for the concerned period 1962 to 2002 in five-year intervals. It was constructed on the basis of the availability of data. Choice of explanatory variables is based partly on an influential paper by Pritchett and Summers (1996), but the present study employs additional customary control variables from other influential papers. Due to missing values, the panel dataset is unbalanced.

Table 1. Descriptive Statistics

Variable	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**	**Cases**
Infant mortality (ln)	4.036	0.866	0.916	5.572	1123
Difference in (ln) infant mortality	-0.154	0.145	-0.853	0.693	957
GDP p.c. (PPP-adjusted; ln)	8.051	1.045	5.460	11.198	1146
Difference in (ln) GDP p.c.	0.079	0.207	-1.441	1.516	986
Schooling (ln)	0.993	0.881	-3.170	2.348	705
Female schooling (ln)	0.654	1.179	-4.423	2.276	703
Male schooling (ln)	1.204	0.751	-2.489	2.446	704
Women’s status (life exp. base)	1.069	0.036	0.946	1.256	1310
Women’s status (schooling base)	0.650	0.285	0.072	1.590	703
Urbanization (ln)	3.556	0.714	0.809	4.605	1420
Food availability (ln)	-2.635	1.926	-11.078	0.585	1111

Note: The data consists of observations of developing countries only.

A variable for infant mortality is a conventional proxy for the living standard of the poor, and hence is employed as a dependent variable. Infant mortality is defined as the number of infants dying before reaching one year of age per 1,000 live births in a given year. A variable for infant mortality is available from Easterly’s (2001) *Global Development Network Growth Database*, released by the World Bank. The country observations of infant mortality for the majority of countries are available beginning from the year 1962 with five-year intervals up to the year 1997.[5] Missing values in the 40-year period from 1962 to 2002 under consideration have been filled by

[5] These data are available beginning from 1960 on a consecutive annual basis for only a very small number of countries. Relying on observations in 1960 is not a good choice in order to maintain a satisfactory number of country observations.

data from *World Development Indicators 2005* published by the World Bank.

As a variable for GDP per capita, this study employs PPP-adjusted GDP per capita in 2000 constant prices in chain series (RGDPCH) from the *Penn World Table Version 6.2* by Heston *et al*. (2006). This latest version of the Penn World Tables series provides six measures of GDP per capita.[6] The main reason for the choice of this specific variable is that RGDPCH is the variable used in Pritchett and Summers (1996) whose empirical findings we re-examine, thus strengthening comparisons with their results. Another reason for employing RGDPCH is that the variable is "the recommended intertemporal GDP time series" (Summers and Heston 1991, p.344) since it mitigates the Laspeyres fixed-base problem in which, as the year-point of the observation is remote from the base year, "relative prices change and the base year weights become less and less appropriate" (Summers and Heston 1991, p.344).

Education is a well-documented factor in reducing infant mortality. The present study employs as a proxy for the level of education the total number of years of schooling in the population over 25 years old in Barro and Lee's (2001) dataset, an earlier version of which is used in Pritchett and Summers' investigation. The data availability is from 1960 to 2000 with five-year intervals. Since our dependent variable — infant mortality — spans the years 1962 to 2002 with five-year intervals, there is a two-year gap between health and schooling variables.

Potentially important determinants of poor people's health are women's social status, urbanization and food availability.[7] Women's social status is a plausible factor in improving infant

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[6] When a variable for GDP per capita is derived from any version of the Penn World Tables, virtually no study clearly specifies the type of GDP per capita variable employed in their studies. A few exceptions include a paper by Pritchett and Summers (1996) which uses RGDPCH. This is exactly why we employ RGDPCH, instead of the other five variables, from the Penn World Tables Version 6.2.

[7] Some may argue that another important determinant of health is health expenditure. However, the link between health expenditure and infant mortality can be quite weak (Filmer and Pritchett 1999; McGuire 2006; Thornton 2002). Therefore, the attention of the present study is directed in seeking more fundamental determinants of the state of health rather than concentrating on health expenditure.

mortality if enhancing the power of women leads resource allocation to be more favorable to family health. Its important role is emphasized in Smith and Haddad (2002), where the female-male life expectancy ratio is treated as a key determinant of the poor's health. The present study uses two different measures of women's social status calculated by: 1) female life expectancy divided by male life expectancy, and 2) female years of schooling divided by male years of schooling.[8]

Urbanization is also likely to be an important factor influencing poverty alleviation and hence is a potential determinant of infant mortality. Particularly in developing countries, child malnutrition is usually lower in urban areas than in rural areas arguably because of better socioeconomic conditions such as piped water (Smith *et al*. 2005). Nevertheless, it is reasonable to suppose that urbanization is a proxy for positive as well as negative determinants of health, since on the positive side it provides access to medical care and health information, while on the negative side it introduces the issues of overpopulation and congestion (Thornton 2002). Many urban areas in developing countries include slum areas having appalling environmental and sanitary conditions, which adversely affect the health of the overall population. In the year 2003, the ratio of slum population to urban population was 72% in Cambodia, 66% in Lao PDR, and 47% in Vietnam (Asian Development Bank *et al*. 2005).[9] As the overall impact of urbanization upon infant mortality is ambiguous, the expected sign of the coefficient on urbanization is *a priori* unknown. A variable for urbanization is proxied for by the proportion of the population who live in urban areas, the data being taken from *World Development Indicators*.

The other potentially important determinant of health is food availability. It is clear that a high level of food availability promotes health in poor households. Mothers' consumption of plentiful food helps to raise the quality of breast milk, which leads to improved infant health. The

[8] The author is aware that the suitability of the female-male life expectancy ratio as a measure of women's status is open to doubt, considering that female life expectancy is higher than the male equivalent for some industrialized countries, while the present study focuses on developing countries.

[9] A crude, but useful definition of slums is "neglected parts of cities where housing and living conditions are appallingly poor" (Asian Development Bank *et al*. 2005, p.213).

importance of food availability for the state of health among the poor is clear, and a lengthy explanation is thus omitted.

3. Empirical Results

3.1. The Effect of GDP per Capita on Infant Mortality

The first stage of statistical procedures examines the relationship between per capita income and infant mortality with conventional control variables.

Table 2. The total effect of per capita income on infant mortality, 1962-2002

	(2-1)	(2-2)	(2-3)	(2-4)	(2-5)	(2-6)	(2-7)	(2-8)	(2-9)	(2-10)	(2-11)
Method:	**Two-way fixed effects**	**Two-way random effects**	**Two-way fixed effects**	**Two-way random effects**	**Two-way fixed effects**	**Two-way random effects**	**Two-way fixed effects**	**Two-way random effects**	**OLS**	**2SLS**	**2SLS Two-way Fixed effects**
(Ln) GDP per capita	-0.255*** (-7.682)	-0.416*** (-15.831)	-0.275*** (-8.455)	-0.408*** (-15.365)	-0.265*** (-8.511)	-0.439*** (-16.835)	-0.199*** (-6.023)	-0.386*** (-14.033)	-0.445*** [-12.451]	-0.397*** (-13.743)	-0.399*** (-4.364)
(Ln) Years of schooling	0.147*** (3.909)	-0.113*** (-3.922)	0.163*** (4.062)	-0.095*** (-2.963)	0.037 (1.001)	-0.154*** (-4.880)	0.051 (1.391)	-0.138*** (-4.506)	-0.402*** [-11.068]	-0.451*** (-15.217)	0.171*** (4.326)
Women's status (life exp.)	-1.158** (-2.282)	-1.131** (-2.382)					-0.801* (-1.651)	-1.082** (-2.417)			
Women's status (schooling)			-0.098 (-1.011)	-0.260*** (-3.002)							
(Ln) Urbanization					0.506*** (8.712)	0.171*** (3.763)	0.411*** (6.769)	0.120*** (2.622)			
(Ln) Food availability							-0.052** (-2.446)	-0.046*** (-3.072)			
Constant	7.227*** (12.751)	8.753*** (16.907)	6.187*** (22.910)	7.611*** (34.187)	4.374*** (13.522)	7.162*** (29.733)	4.959*** (8.342)	7.967*** (15.888)	8.038*** [31.334]	7.705*** (35.775)	7.116*** (9.624)
R^2	0.954		0.956		0.960		0.958		0.696	0.694	0.951
Adjusted R^2	0.945		0.947		0.953		0.950		0.695	0.693	0.941
Akaike Info. Criterion	-3.159		-3.154		-3.286		-3.382		-1.539	-1.534	-3.046
F-statistic (prob.)	F[92, 477] = 106.89 (0.000)		F[93, 481] =112.13 (0.000)		F[91, 474] = 126.07 (0.000)		F[88, 441] = 114.47 (0.000)		F[2, 574] = 656.59 (0.000)	F[2, 574] = 651.05 (0.000)	F[92, 484] = 101.37 (0.000)
Lagrange Multiplier Test (p-value)	824.68 (0.000)		816.86 (0.000)		858.92 (0.000)		715.97 (0.000)				
Hausman Test (p-value)	123.78 (0.000)		112.51 (0.000)		190.92 (0.000)		193.20 (0.000)				
Breusch-Pagan test (p-value)									96.32 (0.000)		
No. of Countries	82		83		81		76		83		83
No. of Observations	570		575		566		530		577		577

Note: Dependent variable: Natural logarithm of infant mortality. The data consists of observations of developing countries only. *t*-statistics are in parentheses. Figures in square brackets are *t*-statistics of heteroscedasticity-corrected White estimators. ***, **, and * indicate significance at the 1%, 5%, and 10% significance level, respectively. Lagrange multiplier tests are for a fixed/random effects model against an OLS model. The Hausman tests a fixed effects model *vs.* a random effects model. The Breusch-Pagan tests heteroscedasticity *vs.* homoscedasticity. For the 2SLS estimations, instrumental variables are investment ratio (CI), openness (OPENC) and market distortion (PPPI).

Table 2 summarizes the estimated results. Results derived from the Hausman test regularly suggest that fixed effects models are more appropriate than random effects models, so the results of fixed effects models are emphasized here. Regressions 2-1 and 2-2 show that, with control variables reflecting schooling and women's status, the estimated coefficient of GDP per capita is negative and significant at the 1% level. Since the double-log form is employed, the coefficient indicates its elasticity. Therefore, under the assumption that causality goes from per capita GDP to infant mortality, the estimated coefficient of per capita GDP suggests that a 1 percent increase in per capita GDP lowers infant mortality by 0.255%. A variable for women's status which is proxied by female life expectancy divided by male life expectancy has a negative, statistically significant coefficient in both fixed and random effects models, suggesting that enhancing women's status helps to decrease infant mortality. Regressions 2-3 and 2-4 employ another variable for women's status which is proxied by gender difference in schooling. The variable of women's status has a negative coefficient in both fixed and random effects models, but is only statistically significant in the random effects model. Regressions 2-5 and 2-6 show that, controlling for a variable of urbanization, its estimated coefficient is statistically significant at the 1% level and has a positive sign, suggesting that urbanization worsens infant mortality. These results are in sharp contrast to those of Smith *et al.* (2005) who found a negative link between child malnutrition and urbanization. This positive sign of the coefficient of urbanization is comprehensible, as discussed in Section 2. Since a large share of the urban population in many developing countries dwell in slums with poor sanitation and infrastructure, urbanization may undermine population health. Regressions 2-7 and 2-8 show that each of the coefficients of food availability is statistically significant and has an expected negative sign, showing that an abundance of food helps to reduce infant mortality.[10] Here too, the estimated coefficient of per capita GDP has a negative sign and is statistically highly significant. Regression

[10] Since a variable for food availability used in this study is calculated by cereal production divided by population, the author is aware that it is not an ideal measure. Nevertheless, there is to my knowledge no internationally comparable alternative.

2-9 shows the OLS estimates. It is well-known that the OLS estimations of cross-country panel data are in all likelihood influenced by heterogeneity across countries. Hence, we present *t*-statistics of heteroscedasticity-corrected White estimators as proposed by White (1980). The Breusch-Pagan (1980) test rejects the null hypothesis of homogeneity and hence strongly indicates heteroscedasiticity between observations in the regression. Regression 2-10 shows the two-stage least square (2SLS) estimation. Reverse causality from a dependent variable (that is, infant mortality) to an independent variable (that is, GDP per capita) is a concern in standard OLS estimation because infant mortality is a health-related variable which can be part of human capital which in turn affects GDP per capita. Appropriate instrumental variables are variables correlated with the explanatory variable of interest (that is, GDP per capita) but not correlated with the residuals of the regression (that is, infant mortality).[11] Instrumental variables must also satisfy independence from unobserved "third" variables determining both GDP per capita and infant mortality. The instrumental variables used here are the ratio of investment to GDP (CI), openness to international trade (OPENC), and market distortion (PPPI). The estimated results of 2SLS (Regression 2-10) are very similar to the OLS estimation (Regression 2-9), that is to say that the estimated coefficient of GDP per capita is negative and statistically significant. This similarity indicates that the statistical findings of the relationship between GDP per capita and infant mortality are not due to reverse causality from infant mortality to GDP per capita. Overall, the negative relationship between GDP per capita and infant mortality is robust across a variety of model specifications and statistical methods, with the addition of control variables. Not surprisingly, these results coincide with the wealthier-healthier proposition.

[11] A popular instrumental variable for GDP per capita employed in Easterly (1999) and Pritchett and Summers (1996) is black market premium, which means the deviation of the official exchange rate from its purchasing power parity. Pritchett and Summers argue that black market premium is an inappropriate instrument for per capita GDP and limit their use of the variable in their investigation. This is because black market premium is highly correlated with social unrest, which can be a potential "third" variable directly influencing both infant mortality and economic growth. The present study does not use it either.

3.2. Partitioning of Income Changes into Economic Booms and Slumps

It is worth stressing that this aggregation of statistical evidence does not guarantee that changes in per capita GDP *in any direction* are correlated with changes in infant mortality. Let us suppose that the effects of income changes on changes in infant mortality are asymmetrical: economic booms and slumps may have different impacts on infant mortality. Either positive income change (that is, booms) or negative income change (that is, slumps) can be strongly linked with a change in infant mortality, but not both. If so, the existing lack of consensus on the growth-poverty relationship in the literature is comprehensible: disagreement may result from whether the specific areas and periods of interest in each investigation experienced economic booms or slumps. To investigate this hypothesis, changes in GDP per capita are divided into "economic booms" when changes in GDP per capita are higher than zero, and otherwise indicated by "economic slumps".

Table 3. The asymmetrical effects of economic booms and slumps upon changes in infant mortality, 1962-2002

	(3-1)	(3-2)	(3-3)	(3-4)	(3-5)	(3-6)	(3-7)	(3-8)
Method:	**OLS [Baseline 1]**	**WLS**	**OLS [Baseline 2]**	**WLS**	**OLS [Baseline 3]**	**WLS**	**OLS [Baseline 4]**	**WLS**
Economic booms: Change in GDP p.c. (Change in GDP p.c. > 0)	0.00058 (0.012) [0.012]	0.216 (7.313)***	0.0066 (0.138) [0.135]	0.208 (7.113)***	0.016 (0.341) [0.332]	0.119 (3.852)***	0.013 (0.280) [0.273]	0.122 (3.898)***
Economic slumps: Change in GDP p.c. (Change in GDP p.c. ≦ 0)	-0.222 (-4.186)*** [-1.931]*	-0.278 (-4.143)***	-0.225 (-4.323)*** [-1.968]**	-0.335 (-4.975)***	-0.248 (-4.791)*** [-2.073]**	-0.327 (-4.684)***	-0.248 (-4.789)*** [-2.072]**	-0.334 (-4.726)***
(Ln) Years of schooling (level)	-0.046 (-7.053)*** [-7.957]***	-0.048 (-6.390)***	-0.043 (-6.197)*** [-6.917]***	-0.032 (-3.742)***	-0.013 (-1.580) [-1.826]*	-0.0035 (-0.378)	-0.013 (-1.532) [-1.770]*	-0.0026 (-0.275)
Women's status [life exp. base] (level)			-0.133 (-0.734) [-0.849]	-0.460 (-4.171)***			0.019 (0.105) [0.116]	-0.082 (-0.673)
(Ln) Urbanization (level)					-0.058 (-5.619)*** [-6.626]***	-0.078 (-7.747)***	-0.059 (-5.609)*** [-6.542]***	-0.074 (-6.437)***
Constant	-0.122 (-12.044)*** [-11.954]***	-0.117 (-12.871)***	0.017 (0.089) [-0.849]	0.343 (3.104)***	0.051 (1.572) [1.787]*	0.113 (3.661)***	0.034 (0.180) [0.203]	0.184 (1.673)*
R^2	0.135	0.135	0.138	0.165	0.186	0.228	0.187	0.229
Adjusted R^2	0.130	0.130	0.131	0.158	0.179	0.222	0.179	0.221
Akaike Info. Criterion	-4.125	-4.814	-4.162	-3.319	-4.215	-3.377	-4.212	-3.374
F-statistic (prob.)	F[3, 494] = 25.76 (0.000)	F[3, 489] = 25.51 (0.000)	F[4, 489] = 19.50 (0.000)	F[4, 487] = 24.08 (0.000)	F[4, 485] = 27.64 (0.000)	F[4, 483] = 35.70 (0.000)	F[5, 483] = 22.23 (0.000)	F[5, 481] = 28.58 (0.000)
Breusch-Pagan test (p-value)	107.51 (0.000)		114.35 (0.000)		133.54 (0.000)		135.89 (0.000)	
No. of Countries	83		82		81		81	
No. of Observations	498		494		490		489	

Note: Dependent variable: Five-year first differences in natural logarithm of infant mortality. Economic booms and slumps are five-year first differences in per capita GDP. The data consists of observations of developing countries only. *t*-statistics are in parentheses. Figures in square brackets are *t*-statistics of heteroscedasticity corrected White estimators. ***, **, and * indicate significance at the 1%, 5%, and 10% significance level, respectively. The Breusch-Pagan tests heteroscedasticity *vs.* homoscedasticity. The weighting variable used in WLS is a variable for population.

Table 3 summarizes the estimated results of the separate effects of per capita income changes upon changes in infant mortality during periods of economic booms and slumps. Regression 3-1 indicates the presence of asymmetry in the impact of positive and negative income changes upon changes in infant mortality. The estimated coefficient of slumps (that is, negative changes in GDP per capita) has an expected negative sign, and is statistically highly significant for *t*-statistics and heteroscedasticity-robust *t*-statistics. Surprisingly, the estimated coefficient of booms (that is, positive changes in GDP per capita) is not statistically different from zero, and has a positive sign. This implies asymmetrical impacts of economic growth on changes in infant mortality: income changes during periods of economic slumps decrease infant mortality, but income changes during periods of economic booms do not necessarily influence infant mortality. The estimated coefficient of schooling has a negative sign and is statistically significant, suggesting that an increase in years of schooling decreases infant mortality. Regression 3-2 implements the WLS method with a variable for population for weighting in order to deal with potential heterogeneity. The *t*-statistic of the coefficient of booms rises sharply, rendering the coefficient highly significant, while its sign remains positive. A large variation in the *t*-statistics for the coefficient of changes in GDP per capita during periods of economic booms suggests that positive economic growth may or may not reduce infant mortality. Regressions 3-3 and 3-4 show that the basic results are robust with the addition of a variable for women's social status. The coefficient of booms has a positive sign and remains statistically insignificant at any conventional level under OLS, but highly significant under WLS estimation. Meanwhile, the variable of slumps has a negative, significant coefficient in both OLS and WLS estimations. In regressions 3-5 and 3-6 where a control variable for urbanization is included, each of the coefficients of economic booms and slumps remains almost the same after its addition. Weighting by population turns the *t*-statistic of the coefficient of booms higher than that of the OLS estimate. The estimated coefficients of urbanization are significant at the 1% level and have negative signs, indicating that urbanization improves infant mortality. These results contrast with those observed in Table 3, where urbanization was found to be positively correlated with infant mortality. Urbanization leads to more people with better access to medical facilities and knowledge, however it also increases the number of poor dwelling in dreadful slum environments. The estimated results reflect the two different effects offsetting each other, and hence the total impact of urbanization upon poverty alleviation is mixed and ambiguous. Regressions 3-7 and 3-8 simultaneously include three control variables for schooling, women's status and urbanization. Here too, each of the estimated coefficients of booms and slumps remains almost identical after the addition of the control variables, which gives further credit to our key findings, that is, asymmetry in the effects of booms and slumps upon changes in infant mortality.

Geographical distribution of observations in those regressions is unbiased as shown in Appendix 2: A third of the observations is from sub-Saharan Africa, another third from Latin America, and the rest from the other areas including east Asia and transitional economies.[12] Furthermore, since not only sub-Saharan countries but also many other developing economies in the observations of the regressions experienced negative economic growth, neither the estimated coefficient of economic booms nor that of economic slumps in the regressions is representative of a small set of countries. Therefore, the empirical findings of the study represent the whole developing world, rather than an exceptional region.

We have shown that dividing changes in income into periods of economic booms and slumps reveals detailed relationships between income changes and infant mortality changes. During periods of economic booms, growth may not be a powerful tool for decreasing infant mortality, but during periods of economic slumps infant mortality receives a devastating impact from economic shrinkage. It is noteworthy that the statistical insignificance of the coefficient of booms may be unexpected, but this is only a little surprising. This finding corresponds with influential evidence reported by Easterly (1999) that a growth effect was found in only half of different regressions where various indicators of the quality of life were regressed on GDP per capita.

[12] It should be remembered that the numbers of observations of the regressions in Table 3 are effectively identical to each other.

Likewise, it should be stressed that the coefficients of slumps is constantly much larger in absolute value than those of booms. Even when economic booms appear to have an undesirable effect on infant mortality (as observed in the WLS estimations), the impact is much smaller than the favorable impact of *positive economic growth achieved during periods of economic slumps*. This means that economic growth is vital in order *not* to increase the victims of infant mortality.

Historical evidence well-documented by Sen (1981, 1999) also agrees well with our findings. In India, the 1943 Bengal famine, in which 1.5 million people died, occurred during an economic boom of its national economy caused by the war boom. In contrast, the Kerala region in India achieved a fast rate of reduction in income poverty despite a moderate rate of economic growth for decades. Moreover, in the Wollo famine in Ethiopia in 1973, low-income households were unable to purchase food although food prices in Wollo were lower than the other areas of the country. Furthermore, the Bangladesh famine in the year 1974 despite a peak level of food availability was caused by regional unemployment, which usually results from economic downturn. These historical experiences indicate that positive economic growth may not always be a powerful tool to reduce poverty, but negative economic growth is expected to worsen poverty.

3.3. Detecting and Deleting Possible Outliers

The problem of possible outliers is an analytical concern worthy of careful scrutiny. It is generally possible that statistical outputs in cross-sectional and panel data analyses are largely influenced by a small number of outliers. Statistical results which are driven by extreme values are uninformative and misleading. If the statistical findings are products of a small number of unrepresentative observations, the results will be dubious.

The Belsley-Kuh-Welsch (1980) method was employed to detect possible outliers. They proposed that observations with standardized residual values exceeding two are possible outliers. Here, three different borderlines of two, three, and four were set, and observations were categorized as possible outliers if their standardized residuals in absolute values were in excess of each borderline. Three groups of possible outliers were detected and then deleted by group in order to test the robustness of the baseline regression models.

Table 4. Excluding possible outliers

	Basic results	Excluding observations u > 4	Excluding observations u > 3	Excluding observations u > 2
Baseline regression 1 (Regression 3-1)				
Booms: Change in GDP p.c.	0.001	-0.025	-0.007	-0.011
(*t*-statistic)	(0.012)	(-0.566)	(-0.159)	(-0.311)
Slumps: Change in GDP p.c.	-0.222***	-0.108**	-0.106**	-0.166***
(*t*-statistic)	(-4.186)	(-2.047)	(-2.182)	(-3.881)
R^2	0.135	0.135	0.144	0.186
[No. of obs.]	[498]	[495]	[490]	[472]
Baseline regression 2 (Regression 3-3)				
Booms: Change in GDP p.c.	0.007	-0.018	-0.009	-0.011
(*t*-statistic)	(0.138)	(-0.419)	(-0.215)	(-0.300)
Slumps: Change in GDP p.c.	-0.225***	-0.111**	-0.107**	-0.175***
(*t*-statistic)	(-4.323)	(-2.160)	(-2.225)	(-4.121)
R^2	0.138	0.137	0.149	0.190
[No. of obs.]	[494]	[491]	[487]	[469]
Baseline regression 3 (Regression 3-5)				
Booms: Change in GDP p.c.	0.016	-0.011	-0.003	0.003
(*t*-statistic)	(0.341)	(-0.265)	(-0.063)	(0.086)
Slumps: Change in GDP p.c.	-0.248***	-0.121**	-0.119**	-0.179***
(*t*-statistic)	(-4.791)	(-2.414)	(-2.496)	(-4.249)
R^2	0.186	0.195	0.205	0.251
[No. of obs.]	[490]	[486]	[483]	[466]
Baseline regression 4 (Regression 3-7)				
Booms: Change in GDP p.c.	0.013	-0.014	-0.006	-0.0002
(*t*-statistic)	(0.280)	(-0.343)	(-0.144)	(-0.007)
Slumps: Change in GDP p.c.	-0.248***	-0.120**	-0.119**	-0.179***
(*t*-statistic)	(-4.789)	(-2.415)	(-2.497)	(-4.253)
R^2	0.187	0.197	0.207	0.253
[No. of obs.]	[489]	[485]	[482]	[465]

Note: The coefficients of control variables, their *t*-statistics, and constants are not shown. ***, **, and * indicate significance at the 1%, 5%, and 10% significance levels, respectively. The model specifications employed here are identical to those in Table 3.

Table 4 demonstrates the robustness tests on the four baseline models of Regressions 3-1, 3-3, 3-5 and 3-7 while excluding potential outliers. In all four models excluding potential outliers according to the three different criteria, the estimated coefficient of economic slumps is always statistically significant at the 5% level and remains negative. Meanwhile, none of the estimated coefficients of economic booms in the four baseline models turns out to be statistically significant at any conventional level. It is also noteworthy that when potential outliers are deleted, the sign of the coefficient of economic booms turns negative in some specifications, while the coefficient remains statistically insignificant at any conventional level. Thus, no evidence was found to indicate that our baseline results are artifacts of outliers. To sum up, our statistical evidence suggests that economic booms have little or mixed impact on infant mortality, while economic slumps have an adverse impact on infant mortality.

4. Conclusions

This study investigated the effects of GDP per capita on infant mortality with panel data for a maximum of 83 developing countries for the period 1962-2002. The main conclusions of the study are two-fold. First, on average, economic growth saves the poor. The country-specific, period-specific effects being controlled, increased per capita GDP decreases infant mortality in developing countries. Statistical procedures verify that this is a causal relationship from GDP per capita to infant mortality. Second, and most innovatively, the impact of economic growth on infant mortality during periods of economic booms and slumps is asymmetrical. The statistical evidence indicates that positive economic growth may or may not help to reduce infant mortality, but economic slumps have an adverse effect on infant mortality. This means that positive economic growth may have weak direct effects on saving infants' lives or may have mixed effects, but an absence of economic growth (*i.e.* negative economic growth) seriously worsens infant mortality. This set of evidence leads us to conclude that economic growth is vital in order *not* to increase the victims of infant mortality. One can *neither* underestimate the importance of economic growth in poverty alleviation *nor* heavily depend on economic growth in the attempt to alleviate poverty. Economic growth is not a magic wand with which to dispel poverty, yet underestimation of economic growth would be a serious error.

Our findings also provide a potential interpretation explaining why little consensus regarding the growth-poverty relationship has been reached in the literature. Conflicting findings in the literature can be explained by discrepancies in economic growth rate in the specific region and period, that is, by whether the concerned region and/or the concerned period was experiencing economic booms or slumps. Putting it differently, those who answer "Yes" to the question "Does growth save the poor?" may base their conclusion primarily on evidence from regions or periods experiencing negative economic growth or stagnation, while those who answer "No" may be focusing on regions or periods experiencing positive economic growth.

Notwithstanding careful scrutiny, this study has three limitations. First, the threshold of positive/negative economic changes (that is, when economic growth rate is zero percent) may not be wholly accurate. When estimating the separate effects of economic changes on changes in infant mortality, the precise borderline might be, say, 1% annual average growth rate, rather than zero percent as adopted in this study. Thus, the zero-percent threshold should be treated as a guideline. Second, empirical studies of developing countries are subject to the restriction of data availability, and this study is no exception. While the above conclusion may reflect an imperfect choice of explanatory variables, it is not free from the effects of restricted data. For example, access to safe water, HIV/AIDS prevention, and health expenditure are notable factors for a healthy life. Inclusion of these variables would reinforce the analysis, but they are unavailable on a longitudinal basis for many developing countries. Further documentation providing internationally comparable data is required. Lastly, this study concentrates on revealing a new broad outline of the growth-poverty relationship, rather than extending our knowledge of the underlying economic channels through which growth influences poverty reduction. Due to the above limitations, this study represents a starting point in the re-examination of the growth-poverty relationship, not an ending. The quest for its true relationship continues.

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Appendix 1. Data Description

Variable name (abbreviation)	***Description and Source (Variable name in data source if necessary)***
Infant mortality rate (INFANT)	Mortality rate, under one year (per 1,000 live births). Source: Mainly from World Development Indicators 2005; For missing values, data are added from Global Development Network Growth Database, World Bank.
Real GDP per capita PPP (RGDPCH)	PPP-adjusted Real GDP per capita (Chain). Source: Penn World Table 6.2 (RGDPCH).
Years of schooling (TYR)	Average years of schooling in the total population (25+). Source: Barro-Lee 2001 (TYR).
Female years of schooling (TYRF)	Average years of schooling in the female population (25+). Note: The figure of average years of schooling in the female population (25+) (*i.e.*, TYRF) in Nepal in the year 1970 scores zero in the data source. The figure is unconvincing partly because the figures 5-years before and after 1970 score 0.042 and 0.037 respectively, and partly because it is hard to believe the averaged years of female schooling in the female population suddenly drops to zero. Treating this particular observation as the outcome of serious measurement error, it is excluded from the dataset of this article. Source: Barro-Lee 2001 (TYRF).
Male years of schooling (TYRM)	Average years of schooling in the male population (25+). Source: Barro-Lee 2001 (TYRM).
Openness (OPENC)	Trade openness: Exports plus imports divided by CGDP (Both numerators and denominators are in current dollars). Source: Penn World Table 6.2 (OPENC).
Market distortion (PPPI)	Price Level of Investment. Source: Penn World Table 6.2 (PI).
Investment-GDP ratio (CI)	Investment share of CGDP (Both numerators and denominators are in current dollars). Source: Penn World Table 6.2 (CI).
Life expectancy (LIFE)	Life expectancy at birth, total (years). Source: Mainly from World Development Indicators 2005; For missing values, data are added from Global Development Network, World Bank.
Female life expectancy (LIFEF)	Life expectancy at birth, female (years). Source: World Development Indicators 2005.
Male life expectancy (LIFEM)	Life expectancy at birth, male (years). Source: World Development Indicators 2005.
Women’s status [life expectancy base] (WSTA1)	Calculated by the author: Female life expectancy divided by male life expectancy.
Women’s status [schooling base] (WSTA2)	Calculated by the author: Female years of schooling divided by male years of schooling.
Urbanization (URBAN)	Urban population (% of total population). Source: World Development Indicators 2005.
Cereal production (CEREAL)	Cereal production (metric tons). Source: World Development Indicators 2005.
Population (POP)	Population, total. Source: World Development Indicators 2005.
Food availability (CPOP)	Calculated by the author: Cereal production (metric tons) divided by population.
OECD dummy (OECD)	Dummy for OECD countries: For the purpose of our research, the countries which joined the OECD after the year 1991 are not categorized as OECD countries. The Czech Republic, Hungary, South Korea, Mexico, Poland and the Slovak Republic score 0 instead of 1. These countries are included in the sample of developing countries. Source: Basically from Global Development Network Growth Database, World Bank.

Appendix 2. Geographical Distribution of Economies (Regression 3-1)

	Names of economies
Sub-Saharan Africa (160)	Benin* (5), Botswana (5), Burundi* (1), Cameroon* (7), Central African Republic* (5), Congo, Dem. Rep.* (5), Congo, Rep.* (4), Gambia* (4), Ghana* (7), Kenya* (7), Lesotho* (7), Liberia* (5), Malawi* (7), Mali* (7), Mauritania (1), Mauritius* (7), Mozambique* (7), Niger* (7), Rwanda* (5), Senegal* (7), Sierra Leone* (5), South Africa* (7), Sudan* (5), Swaziland (5), Togo* (7), Uganda* (7), Zambia* (7),Zimbabwe* (7)
Latin America (152)	Argentina* (7), Barbados* (7), Bolivia* (7), Brazil* (7), Chile* (7), Colombia (7), Costa Rica* (7), Dominican Rep.* (7), Ecuador* (7), El Salvador* (7), Guatemala* (7), Haiti* (5), Honduras* (7), Jamaica* (7), Mexico* (7), Nicaragua* (7), Panama (7), Paraguay* (7), Peru* (7), Trinidad and Tobago* (7), Uruguay* (7), Venezuela* (7)
East Asia (67)	China (4), Fiji* (5), Hong Kong (7), Indonesia* (7), Korea, Rep. (7), Malaysia (7), Papua New Guinea* (5), Philippines (7), Singapore* (8), Taiwan (3), Thailand (7)
Transitional economies (12)	Hungary* (6), Poland* (5), Serbia and Montenegro* (1)
Others (107)	Afghanistan* (5), Algeria* (7), Bahrain* (5), Bangladesh* (5), Cyprus (5), Egypt (4), India (7), Iran* (7), Iraq* (5), Israel (7), Jordan* (4), Kuwait* (5), Malta (5), Nepal (7), Pakistan (7), Sri Lanka (7), Syrian Arab Rep.* (7), Tunisia (7), United Arab Emirates* (1)

Note: Figures in parentheses are the number of observations of the economies which are included in Regression 3-1. Asterisks indicate the economy's experience of a five-year period of negative economic growth.