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SPECIAL THEME: HEALTH AND ECONOMIC CHANGE

Determinants of under-5 mortality among the poor and the rich: a cross-national analysis of 43 developing countries

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Background Under-5 mortality is unacceptably high in many countries, the burden of which is mainly borne by the poor. Whereas country characteristics are known to influence under-5 mortality, it is unknown whether these have a different impact on the poor and the rich. We aimed to describe how the association between under-5 mortality and socioeconomic, political, and health care factors varies in strength between richer and poorer children.

Methods Cross-national analysis of 43 developing countries using wealth-group specific under-5 mortality rates as outcome. Relative effects were estimated using OLS regression; differences in associations between wealth groups were tested.

Results Higher national incomes were associated with lower under-5 mortality rates. This association was significantly weaker for the poor compared with the rich (P = 0.014). Ethnic fragmentation was significantly more strongly associated with higher under-5 mortality among the poor compared with the rich (P = 0.027). The association between public spending on health and under-5 mortality was stronger for the poor (P = 0.0001). Skilled delivery attendance and immunization coverage among the poor were significantly more strongly related to public spending on health than such health care use among the rich (P = 0.0001 and P = 0.045, respectively). No differentials in the relative effect of female literacy, democracy, and state strength were observed.

Conclusion Our results suggest that economic growth is associated with widening poor–rich disparities in under-5 mortality. Increased public spending on health might partly remedy this effect.

Keywords Child mortality, socioeconomic factors, developing countries, income, health expenditures, health services utilization, political factors, ethnic groups, comparative study

Introduction

Some populations are healthier than others. Developing countries exhibit enormous variation in life expectancy and under-5 mortality levels. Under-5 mortality varies from 37/1000 in Colombia to 303/1000 in Niger. National-level determinants of population health explaining differences between countries and trends over time[1,2] have been extensively studied. Female literacy[3–5] and national income[6,7] are well-known determinants, as are political development[8,9] and government commitment to health care.[5,10–12]

However, is what is good on average, also good for the poor? Poorer groups within developing countries systematically exhibit higher under-5 mortality rates than richer groups.[13] Improving the health of the poor is a major objective of national governments and international organizations.[14–16] Imperative to achieving this goal is identifying the causes of high mortality among the poor. These causes have usually been sought at the level of the household, for instance in health-related

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behaviour.[17] Much less is known about the extent to which national-level factors, like government health spending, differentially influence mortality levels of poorer and richer children.

Although all wealth layers may profit from, for example, higher levels of socioeconomic development, not all may benefit equally. Benefit–incidence studies have shown that the rich often profit most from public investments in education and health.[18] This unequal effect has, however, only rarely been studied in relation to health outcomes. Only scattered references occur in the literature, and these focus mainly on the differential mortality effects of public spending on health.[19,20] It is important to answer the same question for a broader set of national-level determinants, as this may provide new insight into the causes of high mortality rates among the poor.

This paper aims to describe to what extent the association between under-5 mortality and well-known socioeconomic, political, and health care factors varies in strength between richer and poorer children within countries. Under-5 mortality is an often-used indicator of population health, and data on under-5 mortality are relatively reliable compared with other measures of population health. Our hypothesis is that country-level determinants of population health interact with the relative position of individuals in the national wealth hierarchy. The importance of this relative position to health has been described in previous studies.[21] As a corollary, the effects of these national-level determinants would vary between poor and rich children. On the basis of the existing literature we would expect socioeconomic improvement to have stronger effects on mortality among the rich,[22,23] and political development and government commitment to health care to have stronger effects on mortality levels among the poor.[19,20] This hypothesis is tested on a cross-national dataset for 43 low-income and middle-income countries, using observed wealth-specific under-5 mortality rates as a dependent variable.

Methods

Data on under-5 mortality for 43 countries in Africa, Asia, and Latin America were obtained from World Bank Country Reports.[13] These reports give, for each of the countries, the under-5 mortality rate for the total population and stratified for five, equally large, wealth groups.

The Country Reports are based on data collected through the Demographic and Health Surveys (DHS) programme.[24] The DHS are nationally representative surveys, for which usually between 5000 and 10 000 women, aged 15–49 years, are interviewed. The surveys include retrospective birth histories, which provide mortality data for individual children. The surveys also include information on household ownership of assets.

In the Country Reports, under-5 mortality was defined as the number of deaths under age 60 months per 1000 live births of those born during the 10 years preceding the survey. Wealth was defined in terms of household ownership of assets. The assets were combined into a wealth index using principal components derived weights.[13,25] This index has been shown to be a good measure of relative economic position in developing countries.[25,26] Wealth groups were constructed such that each consisted of 20% of the survey-population.

Countries for which Country Reports were available at the time of analysis, were included in our study (Table 1).

Explanatory variables

Three types of country characteristics are of particular importance for child survival: the level of socioeconomic development, political development, and government commitment to health. Some of the indicators, such as democracy, are contextual variables by definition. For others, like a country's female literacy rate, there are indications that they exert a contextual effect on mortality above and beyond their individual-level effect.

Socioeconomic development, with GDP (Gross Domestic Product) per capita and female literacy rate as key indicators, is a well-known determinant of under-5 mortality. There is some empirical evidence that economic growth tends to be translated into faster mortality declines among the better-off compared with the poor, and that this might be explained partly by a faster adoption of new health technologies by the more wealthy.[22,23] To account for the well-known curvilinear relationship between income and mortality[6] we used the $\log_{10}$ of real GDP per capita [adjusted for Purchasing Power Parity (PPP)]. Although, the individual-level effects of female literacy on child survival are universally acknowledged, there are indications that female literacy also has effects at the country level over and above those at the individual level.[4] High female literacy rates are thought to be associated with increased overall women's autonomy.[27] Also, they are assumed to reflect 'the capacity of a system to organize and mobilize to fulfil societal necessities'.[28]

There is a lot of debate, both in scientific and political discourse, about the importance of governance for human development.[29] Democracy and state strength are elements of governance that are of main concern. Some studies suggest an effect of democracy or political rights[4,9,27] and state strength[8] on child survival, though this has been debated by others.[30] Our study is the first to empirically describe the strength of the association between democracy and state strength on the one hand, and mortality among poorer and richer children on the other. Democracy, through competition for political power, is thought to make 'politicians more likely to respond to people's needs', thereby being conducive to human development.[29] We have used one of the most, if not the most, often used indicators of democracy and state strength. State strength, measured by tax revenue as percentage of GDP, indicates a state's capacity to extract resources, which can be used for public goods and services.[8,30] Gastil's political rights index was used as a measure of democracy.[31,32] To facilitate interpretation, we recoded the index from a 1 (most democratic) to 7 (least democratic) scale to a 0 (most democratic) to 1 (least democratic) scale.

Ethnic fragmentation, a sociopolitical country characteristic, has been reported to be associated with higher under-5 mortality levels.[33] Ethnic fragmentation, defined as 'the probability that two randomly selected individuals in a country will belong to different ethnolinguistic groups', is closely associated with measures of social polarization and conflict. It has been shown to foster rent-seeking behaviour and to impede decision-making about the provision of public goods.[32]

The effect of public spending on health on under-5 mortality levels is being debated. Whereas some studies find such an effect,[10,11] others find less or no support for this claim.[33] There are also studies that suggest that public spending especially impacts on mortality levels among the poor.[19,20] We calculated public spending on health per capita (in PPP terms) by

Table 1 Descriptive statistics for included outcome and predictor variables

	Mean	Minimum	Maximum	Standard deviation	No. of missing	Reference year	Source
Under-5 mortality population average	126	37	303	63	0	1990–98[a]	Demographic and Health Surveys[9,20]
Under-5 mortality rich	79	20	184	47	0	1990–98[a]	Demographic and Health Surveys
Under-5 mortality next-rich	112	27	315	67	0	1990–98[a]	Demographic and Health Surveys
Under-5 mortality middle	129	31	348	71	0	1990–98[a]	Demographic and Health Surveys
Under-5 mortality next-poor	142	37	355	72	0	1990–98[a]	Demographic and Health Surveys
Under-5 mortality poor	149	43	298	65	0	1990–98[a]	Demographic and Health Surveys
Real GDP per capita (PPP$)	1748	524	4718	1236	0	1990	[b]Human Development Report 1993[33]
Female adult literacy rate (%15+)	53	9	99	27	0	1990	Human Development Report 1993[c]
Measure of democracy[d]	5.0	2	7	1.7	4	1980	Easterly and Levine dataset[27]
Index of ethnic fragmentation[e]	0.59	0.01	0.93	0.29	7	1960	Easterly and Levine dataset
Tax revenue (% of GDP)	13.9	5.9	29.3	6.0	8	1990	World Development Indicators 2002[34]
Public health expenditure per capita (PPP$)	41.8	8.4	137.3	36.9	0	1990	[f]World Development Report 1993[35]
Immunization coverage population average[g]	50	11	82	19	1	1990–98[a]	Demographic and Health Surveys
Immunization coverage rich	66	23	95	15	1	1990–98[a]	Demographic and Health Surveys
Immunization coverage next-rich	56	17	93	19	1	1990–98[a]	Demographic and Health Surveys
Immunization coverage middle	50	6	85	22	1	1990–98[a]	Demographic and Health Surveys
Immunization coverage next-poor	46	9	80	21	1	1990–98[a]	Demographic and Health Surveys
Immunization coverage poor	38	4	83	20	1	1990–98[a]	Demographic and Health Surveys
Skilled delivery attendance population average[h]	52	8	100	23	0	1990–98[a]	Demographic and Health Surveys
Skilled delivery attendance rich	84	30	100	17	0	1990–98[a]	Demographic and Health Surveys
Skilled delivery attendance next-rich	66	9	100	25	0	1990–98[a]	Demographic and Health Surveys
Skilled delivery attendance middle	51	4	99	28	0	1990–98[a]	Demographic and Health Surveys
Skilled delivery attendance next-poor	42	3	100	28	0	1990–98[a]	Demographic and Health Surveys
Skilled delivery attendance poor	31	2	99	26	0	1990–98[a]	Demographic and Health Surveys

Included countries were: (Africa): Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Comores, Côte d'Ivoire, Ghana, Kenya, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Senegal, Tanzania, Togo, Uganda, Zambia, Zimbabwe; (Asia): Bangladesh, India, Indonesia, Nepal, Pakistan, Philippines, Vietnam; (Latin America): Bolivia, Brazil, Colombia, Dominican Republic, Guatemala, Haiti, Nicaragua, Paraguay, Peru; (Other): Kazakhstan, Kyrgyz Republic, Morocco, Turkey, Uzbekistan.

[a] Years in which the DHS surveys were conducted.

[b] For 5 countries with missing data, the Human Development Report 1994 and 1996 were used (reference years 1991 and 1993).

[c] For 9 countries with missing data, the Human Development Report 1992 and 1998 were used (reference years 1990 and 1995).

[d] Gastil's political rights index: 1 (most democratic) to 7 (least democratic); 1980 is the latest year available from the dataset used.

[e] Gives the probability that two randomly selected individuals in a country will belong to different ethnolinguistic groups.

[f] For 2 countries with missing data, the Human Development Report 2002 was used (reference year 1990).

[g] Proportion of surviving children, aged 12–23 months at time of the survey, who received BCG, measles, three doses of DPT, and oral polio vaccines.

[h] Proportion of deliveries attended by a medically trained person (i.e. doctor, nurse, or nurse-midwife) during the 5 years preceding the survey.

multiplying public spending on health as percentage of GDP by GDP per capita (PPP). The $\log_{10}$ of public health spending was taken, as this has been shown in previous literature to be the appropriate functional form.[10]

The data used are for 1990, unless otherwise stated (Table 1). Hence, the reference year of the explanatory variables falls roughly in the same period as the included birth histories.

Statistical analysis

The associations between the determinants and under-5 mortality were studied using OLS linear regression analysis, following the example of influential papers.[33,34] First, the univariate relationship between mortality and each of the determinants was studied. Next, confounders that a priori were considered important—female literacy, ($\log_{10}$) GDP per capita, and region—were added to the model. Female literacy and GDP per capita are probably the most universally acknowledged country-level determinants of under-5 mortality, as well as being closely associated with the performance of countries in a range of other dimensions, including those studied here. 'Region' captures a whole set of, among others, historical, geographical, and cultural factors, that are associated both with under-5 mortality and with the explanatory variables

studied. By adding dummies for regions as confounder to the model, we were able to adjust for this entire range of potential confounders.

The effects of the explanatory variables were expressed in relative terms, as is conventional in research studying health outcomes. Relative effects of the explanatory variables were obtained by using the $\log_{10}$ of under-5 mortality (U5M). Relative effects, measured in rate ratios, were calculated by taking 10 to the power of the (unstandardized) regression coefficients of the explanatory variables, yielding the factor by which under-5 mortality changes, given a change in the explanatory variable of 1 unit. As rate ratios >1 are intuitively easier to interpret, the explanatory variables were coded such that 0 indicated the highest or most 'desirable' value, and 1 the lowest or least 'desirable' value. Since the $\log_{10}$ was used for GDP and health spending, the rate ratio in these cases indicates the factor by which mortality changes upon a 10-fold change in the explanatory variable.

First, we estimated the effects of the explanatory variables for the total population and per wealth quintile. The formula for the analysis of the effect of GDP per capita on under-5 mortality, corrected for female literacy (Flit) is presented as an example. Dummies for regions were handled in the model analogous to female literacy.

For every single wealth quintile we fitted

$$\log(\mathrm{U5M}_i) = b_0 + b_1\ \log(\mathrm{GDP})_i + b_2 \mathrm{Flit}_i + \epsilon \quad \epsilon \sim N(0, \sigma^2) \quad (1)$$

where i stands for country.

This is exactly the same analysis as can be performed for the total population, and leads to the effect sizes and confidence intervals presented in Table 2.

Then, to test whether there was a linear trend in the effect of explanatory variables across wealth quintiles, we collapsed the five quintile specific datasets into one large dataset. If all parameters in the analysis using the collapsed dataset were made quintile-specific, the results would be identical to the ones estimated by using Equation (1). Instead, we restricted the quintile specific parameters b_{1q} in such a way that they lay on a straight line. This was done by replacing b_{1q} with $b_{11} + b_t(q-1)$, where q is wealth class as a continuous variable. This construction in effect means that the differences between adjacent b_{1q}'s are constant with value b_t. By adding, in the collapsed dataset, country as a categorical variable to the model, we ensured that differences in mean mortality level between countries are removed from the error term, thereby enhancing the power of the analysis. Again, the formula for the analysis of the effect of GDP per capita on under-5 mortality, corrected for female literacy is presented as an example.

$$\log(U5M_{iq}) = b_{0i} + [b_{11} + b_t(q-1)]\ \log(GDP)_i + b_{2q} Flit_i + \epsilon \quad \epsilon \sim N(0, \sigma^2) \quad (2)$$

where b_{0i} represent different intercepts for each country, which is the same as adding country as a categorical variable to the model.

The residual number of degrees of freedom for model 2 is 43*5 (number of observations) −43 (different intercepts for country) −1 (trend for GDP) −4 (interaction parameters for Flit). As the different intercepts for country are merely nuisance variables (uncorrelated with the effects of interest), the model fits essentially five parameters with 167 residual degrees of freedom. This implies that the number of observations is adequate to fit the model reliably.

Two additional analyses were performed to explore two main findings of this paper in further depth. First, we assessed whether the significantly stronger effect of GDP on richer groups (see Results section) could be explained by an unequal distribution of income within countries. For this purpose, income inequality was added as fourth confounder to the models for GDP. This was done for two measures of income inequality, the gini-index and the share of income or consumption of the richest to the poorest 20% population group.

Second, we assessed whether the significantly stronger effect of public spending on health on mortality levels among the poor (see Results section), could be explained by a stronger effect of such spending on health care utilization in this group. For this purpose, we used public spending on health as an explanatory variable for (i) full childhood immunization coverage and (ii) skilled delivery attendance, using a similar line of analysis as described above.

To make optimal use of the data, the number of countries included was allowed to vary according to the number of missing

Table 2 Relative effect of socioeconomic development on under-5 mortality

	Effects on under-5 mortality				
	GDP per capita[a]			Female literacy[a]	
Wealth group	Univariate	Adjusted for female literacy, region (95% CI)	Adjusted for female literacy, region, gini-index (95% CI)	Univariate	Adjusted for GDP, region (95% CI)
Total	4.41 (3.13–6.21)	1.95 (1.28–2.97)	1.95 (1.27–2.99)	4.90 (3.39–7.10)	2.50 (1.71–3.65)
Rich	5.99 (4.08–8.81)	2.35 (1.45–3.82)	2.35 (1.44–3.83)	5.90 (3.85–9.04)	2.20 (1.42–3.42)
Fairly-rich	5.55 (3.77–8.15)	2.39 (1.47–3.89)	2.39 (1.47–3.90)	6.04 (3.94–9.26)	2.68 (1.73–4.16)
Middle	5.00 (3.40–7.35)	2.35 (1.45–3.83)	2.35 (1.45–3.83)	5.63 (3.67–8.63)	2.77 (1.78–4.29)
Fairly-poor	4.93 (3.35–7.24)	2.01 (1.24–3.27)	2.01 (1.24–3.27)	5.61 (3.66–8.59)	2.73 (1.76–4.24)
Poor	3.35 (2.28–4.93)	1.49 (0.92–2.42)	1.49 (0.92–2.43)	3.81 (2.49–5.85)	2.25 (1.45–3.49)
P-value trend test[b]		0.014	0.013		0.874

[a] Regression based estimates of under-5 mortality rate ratios indicating the decrease in under-5 mortality associated with a 10-fold increase in GDP per capita and an increase in female literacy from 0 to 100%, respectively.

[b] *P*-value for test on linear trend in the effect of the explanatory variable across wealth quintiles.

cases per explanatory variable. The analyses were performed with GLIM4.[35]

Results

The countries included varied widely, both in terms of level of development and in the extent of ethnic fragmentation (Table 1). Furthermore, the mean under-5 mortality rate among poorer children was much higher than that among richer ones.

In countries with a 10-fold higher GDP per capita, total under-5 mortality was on average a 4.4-fold lower (95% CI 3.1–6.2) (Table 2). After adjustment for female literacy, the effect of GDP was 2.4 (results not shown). Additional adjustment for region further reduced the effect to 1.95 (Table 2), meaning that, after adjustment, a 10-fold higher GDP per capita was associated with an almost 2-fold lower mortality rate.

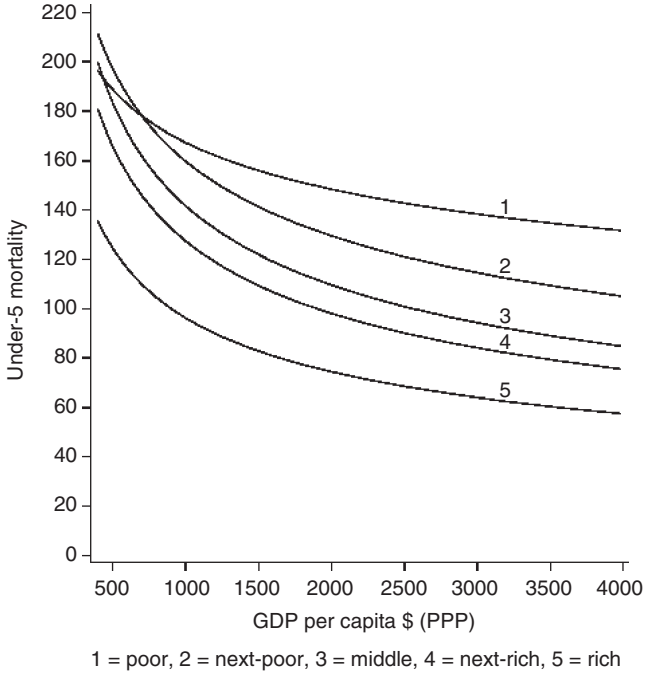

Figure 1 Differential effect of GDP on under-5 mortality of the five wealth groups, controlled for female literacy and region, taking 50% literacy and Africa as reference groups

There was a statistically significant linear trend in the effect of GDP per capita across wealth groups, showing weaker effects on under-5 mortality among the poor ($P = 0.014$). This is illustrated by smaller reductions in under-5 mortality among the poor compared with the rich, upon increases in GDP (Figure 1). The lack of distinction in mortality levels among the poorest four groups at low levels of GDP is empirically observed in many African countries. The significantly weaker effect of GDP on mortality levels among the poor remained after adjusting for the income distribution within countries, measured using the gini-index (Table 2). Practically the same was observed when using the share of income or consumption of the richest to the poorest 20% population group (results not shown).

Higher female literacy rates were strongly and significantly associated with lower total under-5 mortality, also after adjusting for confounders. The adjusted effect of female literacy, however, did not vary significantly between poorer and richer children.

More democratic and ethnically homogeneous countries showed, in the univariate analysis, significantly lower total under-5 mortality rates (Table 3). After adjusting for confounding, only state strength was slightly, though significantly, associated with lower total under-5 mortality. The strength of this association was comparable across wealth groups. Although the effect of ethnic homogeneity on total under-5 mortality was not significant after adjusting for confounders, a significant linear trend in the effect was observed across wealth groups. Ethnic fragmentation was more strongly associated with higher under-5 mortality among the poor compared with the rich ($P = 0.027$).

Public spending on health was slightly and not significantly related to total under-5 mortality after adjusting for GDP, female literacy, and region (Table 4). However, the effects of public spending differed strongly and significantly between wealth groups, showing stronger effects on the mortality level among poor children ($P = 0.0001$).

Table 3 Relative effect of political factors on under-5 mortality

	Effects on under-5 mortality					
	Democracy[a]		State strength[a]		Ethnic fragmentation[a]	
Wealth group	Univariate	Adjusted for female literacy, GDP, region (95% CI)	Univariate	Adjusted for female literacy, GDP, region (95% CI)	Univariate	Adjusted for female literacy, GDP, region (95% CI)
Total	2.14 (1.25–3.67)	1.16 (0.86–1.56)	1.29 (0.98–1.70)	1.17 (1.01–1.35)	2.74 (1.64–4.58)	1.11 (0.74–1.66)
Rich	2.67 (1.47–4.84)	1.17 (0.85–1.62)	1.27 (0.94–1.73)	1.13 (0.95–1.33)	3.29 (1.84–5.89)	0.84 (0.53–1.31)
Next-rich	2.67 (1.47–4.85)	1.24 (0.90–1.72)	1.29 (0.95–1.76)	1.13 (0.96–1.34)	3.26 (1.82–5.82)	1.05 (0.67–1.64)
Middle	2.47 (1.36–4.49)	1.26 (0.91–1.74)	1.41 (1.04–1.92)	1.24 (1.05–1.47)	2.99 (1.67–5.34)	1.05 (0.67–1.65)
Next-poor	2.05 (1.13–3.71)	1.08 (0.78–1.49)	1.30 (0.96–1.78)	1.16 (0.98–1.37)	3.00 (1.68–5.36)	1.21 (0.77–1.90)
Poor	1.78 (0.98–3.23)	1.12 (0.81–1.55)	1.23 (0.91–1.68)	1.16 (0.98–1.37)	2.30 (1.29–4.11)	1.17 (0.75–1.83)
P-value trend test[b]		0.373		0.609		0.027

[a] Regression based estimates of under-5 mortality rate ratios indicating the decrease in under-5 mortality associated with a change from least to most democratic, with an increase in taxing from 0% of GDP to 10% of GDP, and with a change from extremely ethnically fragmented to ethnically homogeneous, respectively.

[b] *P*-value for test on linear trend in the effect of the explanatory variable across wealth quintiles.

Table 4 Relative effect of public spending on health on under-5 mortality and on full immunization coverage and skilled delivery attendance

	Public spending on health per capita[a]					
	Effects on under-5 mortality		Effects on full immunization coverage[b]		Effects on skilled delivery attendance[c]	
Wealth group	Univariate	Adjusted for female literacy, region, GDP (95% CI)	Univariate	Adjusted for female literacy, region, GDP (95% CI)[a]	Univariate	Adjusted for female literacy, region, GDP (95% CI)[b]
Total	2.41 (1.58, 3.66)	1.10 (0.75, 1.61)	1.33 (0.90, 1.97)	1.09 (0.56, 2.11)	2.42 (1.54, 3.82)	1.19 (0.70, 2.03)
Rich	2.32 (1.45, 3.71)	0.61 (0.40, 0.94)	0.95 (0.60, 1.52)	0.86 (0.40, 1.87)	1.38 (0.75, 2.53)	0.92 (0.44, 1.93)
Fairly-rich	2.54 (1.59, 4.05)	0.90 (0.58, 1.38)	1.23 (0.77, 1.97)	1.00 (0.46, 2.16)	2.18 (1.19, 4.00)	0.80 (0.38, 1.67)
Middle	2.61 (1.63, 4.17)	1.11 (0.72, 1.71)	1.54 (0.96, 2.45)	1.02 (0.47, 2.20)	3.10 (1.69, 5.69)	0.98 (0.47, 2.06)
Fairly-poor	2.73 (1.71, 4.36)	1.23 (0.80, 1.89)	1.61 (1.01, 2.58)	1.27 (0.59, 2.75)	3.80 (2.07, 6.99)	1.59 (0.75, 3.33)
Poor	2.28 (1.43, 3.64)	1.47 (0.96, 2.26)	1.77 (1.11, 2.83)	1.28 (0.59, 2.77)	4.43 (2.41, 8.14)	2.25 (1.07, 4.73)
P-value trend test[d]		0.0001		0.045		0.0001

[a] Regression-based estimates of under-5 mortality rate ratios indicating the decrease in under-5 mortality associated with a 10-fold increase in public spending on health per capita per capita.

[b] Regression-based estimates of full immunization coverage rate ratios indicating the increase in full immunization coverage associated with a 10-fold increase in public spending on health per capita.

[c] Regression-based estimates of skilled delivery attendance prevalence rate ratios indicating the increase in skilled delivery attendance prevalence associated with a 10-fold increase in public spending on health per capita.

[d] *P*-value for test on linear trend in the effect of the explanatory variable across wealth quintiles.

Health care use among the poor was significantly more strongly associated with levels of public spending on health than health care use among the rich. We observed this for full childhood immunization coverage (*P*-value for trend test = 0.045) and for skilled delivery attendance ($P = 0.0001$).

Discussion

Our study shows that national-level determinants of under-5 mortality can have a different effect on the poor and the rich. The association between national per capita income and under-5 mortality was significantly stronger among the rich compared with the poor. In contrast, the association between public spending on health and under-5 mortality was significantly stronger among the poor. Ethnic fragmentation was significantly more strongly associated with higher under-5 mortality rates among the poor compared with the rich. No differentials in the relative effect of female literacy, democracy, and state strength were observed.

Evaluation of data and methods

Our study describes, for low-income and middle-income countries, how under-5 mortality rates vary with the national-level context. Differences between countries have often materialized over longer periods of time. We have described those tendencies that could be captured cross sectionally, and have included no time-trends or lagged effects.

The large number of developing countries for which comparable data on under-5 mortality in different wealth layers are available, combined with the heterogeneity of these countries in terms of mortality and its determinants, and the possibility to statistically adjust for important confounders, makes the quantitative cross-country comparative design used particularly valuable. The importance of international comparisons for the analysis of country-level effects has been underlined by others,[36] and the quantitative cross-national study design used, is very common in development studies, political sciences, and sociology.[6–9,30] Such comparisons complement evidence that is available from time-trend analyses. The little information that is available on time-trends in developing countries confirms some of our main conclusions. Relative socioeconomic mortality inequalities, for example, appear to increase in periods of economic growth.[22,37,38]

Caution must, however, be exercised when interpreting the observed statistical effects as causal effects. In our analyses, we corrected for the two most probable confounders, female literacy rate and GDP per capita, and for a third, region, which captures a whole set of factors that could act as confounders. However, the possibility of uncontrolled confounding cannot be excluded. Unfortunately, a lack of wealth-specific mortality data for a larger set of countries inhibits the use of more elaborate models.

Reverse causation is less likely to be an alternative explanation for the observed differences in effect between wealth groups. The causal effect of GDP on population health has been demonstrated in previous research.[7] Moreover, it seems unlikely that lower mortality rates among the poor would cause an increase in public spending on health or a decrease in ethnic fragmentation.

Our definition of wealth is a relative one, describing the position of children in the national wealth hierarchy. This was partly a pragmatic choice, as mortality data stratified by relative status are readily available for a large number of developing countries, whereas for absolute economic status they are not. But even if such data would exist, it would probably remain difficult to assess, in a cross-national analysis, trends in effect across absolute wealth groups within countries. In many countries, the rich, in absolute terms, are virtually non-existent, whereas in other countries, the poor, in absolute terms, are almost non-existent. In Mali, for example, 73% of the population lives below the poverty-line of $1 a day, whereas this is only 3% in the Dominican Republic.[39] The importance of relative

socioeconomic position for one's health has been emphasized in earlier studies.[21] More importantly, our approach is consistent with Rogers' influential diffusion of innovations theory.[40] According to this theory, societal changes spread unequally through a population, reaching higher socioeconomic classes first before reaching the lower classes.[22,23] If national income rises, for example, it would be the relatively rich that would first reap the benefits in terms of improved survival. The results of our cross-sectional analysis were consistent with this hypothesis: the association between GDP per capita and under-5 mortality levels was stronger among the relatively rich.

We studied a broad set of countries, mostly in Africa, Asia, and Latin America. However, as no data were available for Middle-Eastern countries at the time of analysis, our findings cannot necessarily be generalized to this region.

For the above reasons, it is important to interpret our results with some caution. At the same time, they are an important first step in the new research field of contextual determinants of population health and can be used as a basis for further research.

Furthermore, while research on health outcomes conventionally uses relative effect measures, such as rate ratios, effects expressed in absolute terms, such as rate differences, do not necessarily yield the same results.[41] Illustrative is our finding of significantly stronger absolute effects of a country's female literacy rate on mortality levels among poor children ($P = 0.009$) (results available upon request). So, whereas in relative terms, the effect of female literacy appeared the same for the rich and poor, absolute effects were significantly stronger for the poor.

Explaining the results

The stronger effect of national per capita income on mortality levels among the rich was not explained by the income distribution within countries. Our findings correspond to those of Victora[23] and Wagstaff,[22] whose findings suggest that the stronger effect of national income on the rich is possibly due to a faster assimilation of new health technologies by the better-off.

Ethnic fragmentation has been shown to be associated with high under-5 mortality in a previous study.[33] Our finding that ethnic fragmentation appears to have small, but significantly stronger, effects on the poor than on the rich is a new one. This was especially observed for Africa, where the degree of fragmentation differs greatly between countries. In ethnically fragmented countries, entitlements[27] to material and other resources important for child survival, might be distributed along ethnical lines. In these countries, therefore, being poor, not only means having no money, but possibly also being deprived of entitlements to resources like health care. Our findings run parallel to another study, which found that ethnic fragmentation in Africa is liable to result in high income inequality.[42]

Some studies have suggested that democracy has a role in reducing poor–rich inequalities in childhood mortality. As democratic governments have to listen to their electorate, public policies would be more pro-poor, particularly in countries where the majority of the electorate is poor. Our study is the first to show that if an association exists, it is comparable across wealth groups.

The effect of public spending on health on mortality rates is much debated. Our results support studies that find an effect especially on the poor.[19,20] Preliminary results of a stratified analysis suggest that this applies equally to countries with a low and with a relatively high GDP per capita (results not shown). The significantly stronger effects of public spending on under-5 mortality among the poor are missed when only aggregate mortality levels are studied.[33] The observed negative effects on the rich, and maybe also the small effects on the total population, may have been affected by a special multicollinearity problem due to a strong association between GDP and public spending ($r = 0.77$). The stronger effect of public spending on health on poorer children is possibly explained by the significantly stronger responsiveness of the utilization of primary care among these households to increases in such spending.

Cross-national studies like ours give complementary insight into the effects of public spending in comparison with benefit–incidence studies, which often study one country or programme. Benefit–incidence studies combine information about the costs of the provision of public services with the use of these services.[18] Such studies reveal that the distribution of public spending tends to favour the better-off. Apparently, even though in monetary terms public spending favours the rich, the effects in mortality terms are likely to be larger for the poor. Further research would be needed to assess how this money is spent most effectively for the benefit of the poor, for example through selective or comprehensive primary care.

Implications

The well-known 'Preston-curve', showing the relationship between national income and life expectancy or child mortality, can be refined with a flatter curve for poorer children within countries and a steeper curve for richer ones. Our findings suggest that economic growth is, on average, associated with widening poor–rich mortality disparities in under-5 mortality. Increased public spending on health might partly remedy this effect. Our results suggest that such spending might be an important tool to improve child survival among the poor.

Although ethnic fragmentation itself is not amenable to change, our findings suggest that understanding social and cultural barriers to mortality reduction could be important when tackling the high mortality rates among the poor.

Conclusion

Differential effects on poorer and richer children of such a broad range of country characteristics have not been reported before. Our study shows that the conventional focus on average effects of national-level determinants of population health can conceal important differences in effect between subgroups. In addition, the primary focus in the existing literature on household-level causes of high mortality among the poor may distract attention from important, and more structural, determinants at the national level. Households are not autonomous units. Therefore,

the causes of under-5 mortality cannot be fully unravelled by zooming-in on household-level factors alone. Zooming-out to country, region, or even global-level determinants of under-5 mortality, and especially studying their interaction with the economic position of individuals, is of fundamental importance.

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KEY MESSAGES

- A strong gradient in under-5 mortality according to household wealth has been established for a large number of low-income and middle-income countries.
- The association between national per capita income and under-5 mortality was significantly stronger for the rich, whereas the association between public spending on health and under-5 mortality was significantly stronger for the poor.
- Health care use among the poor was significantly more strongly associated with levels of public spending on health than health care use among the rich.
- Our results suggest that economic growth is associated with widening poor–rich disparities in under-5 mortality. Increased public spending on health might partly remedy this effect.

References

[1] McKeown T. *The Role of Medicine: Dream, Mirage, or Nemesis?* London: Nuffield Provincial Hospitals Trust, 1976.

[2] Szreter S. Rethinking McKeown: the relationship between public health and social change. *Am J Public Health* 2002;**92:**722–25.

[3] Cleland JG, Van Ginneken JK. Maternal education and child survival in developing countries: the search for pathways of influence. *Soc Sci Med* 1988;**27:**1357–68.

[4] Caldwell JC. Health transition: the cultural, social and behavioural determinants of health in the Third World. *Soc Sci Med* 1993;**36:**125–35.

[5] Caldwell JC. Routes to low mortality in poor countries. *Popul Dev Rev* 1986;**12:**171–220.

[6] Preston SH. The changing relation between mortality and level of economic development. *Popul Stud* 1975;**29:**231–48.

[7] Pritchett L, Summers LH. Wealthier is healthier. *J Hum Resour* 1996;**31:**841–68.

[8] Shen C, Williamson JB. Child mortality, women's status, economic dependency, and state strength: a cross-national study of less developed countries. *Soc Forces* 1997;**76:**667–700.

[9] Frey RS, Al-Roumi A. Political democracy and the physical quality of life: the cross-national evidence. *Soc Indic Res* 1999;**47:**73–97.

[10] Gupta S, Verhoeven M, Tiongson ER. The effectiveness of government spending on education and health care in developing and transition economies. *Eur J Political Econ* 2002;**18:**717–37.

[11] Anand S, Ravallion M. Human development in poor countries: on the role of private incomes and public services. *J Econ Perspect* 1993;**7:**133–50.

[12] Halstead SB, Walsh JA, Warren KS, (eds). *Good Health at Low Cost*. New York: Rockefeller Foundation, 1985.

[13] Gwatkin DR, Rutstein S, Johnson K, Pande RP, Wagstaff A. *Socio-economic Differences in Health, Nutrition, and Population*. Washington: The World Bank, 2000.

[14] WHO. *The World Health Report 1999: Making a difference*. Geneva: World Health Organization, 1999.

[15] World Bank. *Sector Strategy: Health, Nutrition, and Population*. Washington, DC: World Bank, 1997.

[16] Evans T, Whitehead M, Diderichsen F, Bhuiya A, Wirth M, (eds). *Challenging Inequities in Health: From Ethics to Action*. Oxford: Oxford University Press, 2001.

[17] Schellenberg JA, Victora CG, Mushi A *et al*. Inequities among the very poor: health care for children in rural southern Tanzania. *Lancet* 2003;**361:**561–66.

[18] Castro-Leal F, Dayton J, Demery L, Mehra K. Public spending on health care in Africa: do the poor benefit? *Bull World Health Org* 2000;**78:**66–74.

[19] Bidani B, Ravallion M. Decomposing social indicators using distributional data. *J Econom* 1997;**77:**125–39.

[20] Gupta S, Verhoeven M, Tiongson ER. Public spending on health care and the poor. *Health Econ* 2003;**12:**685–96.

[21] Wilkinson RG. *Unhealthy Societies: The Afflictions of Inequality*. London: Routledge, 1996.

[22] Wagstaff A. *Inequalities in health in developing countries: swimming against the tide? Policy Research Working Paper 2795*. Washington, DC: World Bank, 2002.

[23] Victora CG, Vaughan JP, Barros FC, Silva AC, Tomasi E. Explaining trends in inequities: evidence from Brazilian child health studies. *Lancet* 2000;**356:**1093–98.

[24] Available at: www.measuredhs.com.

[25] Filmer D, Pritchett LH. Estimating wealth effects without expenditure data—or tears: an application to educational enrollments in states of India. *Demography* 2001;**38:**115–32.

[26] Bollen KA, Glanville JL, Stecklov G. Economic status proxies in studies of fertility in developing countries: does the measure matter? *Popul Stud J Demogr* 2002;**56:**81–96.

[27] Sen A. *Development as Freedom*. Oxford: Oxford University Press, 1999.

[28] Palloni A. Mortality in Latin America: emerging patterns. *Popul Dev Rev* 1981;**7:**623–49.

[29] UNDP. *Human Development Report 2002: Deepening democracy in a fragmented world*. Oxford: Oxford University Press, 2002. p. 56.

[30] Frey RS, Field C. The determinants of infant mortality in the less developed countries: a cross-national test of five theories. *Soc Indic Res* 2000;**52:**215–34.

[31] Gastil RD. The comparative survey of freedom: experiences and suggestions. *Stud Comp Int Dev* 1990;**25:**25–50.

[32] Easterly W, Levine R. Africa's growth tragedy: policies and ethnic divisions. *Q J Econ* 1997;**112:**1203–50.

[33] Filmer D, Pritchett L. The impact of public spending on health: does money matter? *Soc Sci Med* 1999;**49:**1309–23.

[34] Gupta S, Verhoeven M, Tiongson E. *Public Spending on Health Care and the Poor*. IMF Working Paper WP/01/127. IMF, 2001.

[35] Francis B, Green M, Payne C. *The GLIM System*. Oxford: Clarendon Press, 1993.

[36] Lu TH, Chiang TL, Lynch JW. What can we learn from international comparisons of social inequalities in road traffic injury mortality? *Inj Prev* 2005;**11:**131–33.

[37] Vega J, Hollstein RD, Delgado I *et al*. Chile: socioeconomic differentials and mortality in a middle-income nation. In: Evans T, Whitehead M, Diderichsen F, Bhuiya A, Wirth M, (eds). *Challenging Inequities in Health: From Ethics to Action*. Oxford: Oxford University Press, 2001.

[38] DaVanzo J, Habicht J-P. Infant mortality decline in Malaysia, 1946-1975: the roles of changes in variables and changes in the structure of relationships. *Demography* 1986;**23:**143–60.

[39] UNDP. *Human Development Report 2000*. New York: UNDP, 2000.

[40] Rogers EM. *Diffusion of Innovations*. London: Free Press, 2003 [1962].

[41] Boström G, Rosén M. Measuring social inequalities in health–politics or science? *Scand J Public Health* 2003;**31:**211–15.

[42] Milanovic B. *Is inequality in Africa really different?*; Washington: The World Bank, 2003, pp. 1–44.