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Socioeconomic determinants of infant mortality: A worldwide study of 152 low-, middle-, and high-income countries

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Abstract

Background: To reach the Millennium Development Goals for health, influential international bodies advocate for more resources to be directed to the health sector, in particular medical treatment. Yet, health has many determinants beyond the health sector that are less evident than proximate predictors. *Aim*: To assess the relative importance of major socioeconomic determinants of population health, measured as infant mortality rate (IMR), at country level. *Methods*: National-level data from 152 countries based on World Development Indicators 2003 were used for multivariate linear regression analyses of five socioeconomic predictors of IMR: public spending on health, GNI/capita, poverty rate, income equality (Gini index), and young female illiteracy rate. Analyses were performed on a global level and stratified for low-, middle-, and high-income countries. *Results*: In order of importance, GNI/capita, young female illiteracy, and income equality predicted 92% of the variation in national IMR whereas public spending on health and poverty rate were non-significant determinants when adjusted for confounding. In low-income countries, female illiteracy was more important than GNI/capita. Income equality (Gini index) was an independent predictor of IMR in middle-income countries only. In high-income countries none of these predictors was significant. *Conclusions*: The relative importance of major health determinants varies between income levels, thus extrapolating health policies from high- to low-income countries is problematic.

Since the size, per se, of public health spending does not independently predict health outcomes, functioning health systems are necessary to make health investments efficient. Potential health gains from improved female education and economic growth should be considered in low- and middle-income countries

Key Words: *Child mortality, female literacy, Gini index, GNI, infant mortality rate, health determinant, health expenditure, health system, poverty, socioeconomic*

Background

A steady decline in IMR in all countries during the last century has come to a halt in many countries and even begun to reverse in some sub-Saharan African countries heavily burdened by HIV/AIDS [1], Globally, there is a 60-fold variation in infant mortality rate (IMR) from a high of 182/1,000 live births in Sierra Leone to only 3/1,000 in Sweden [2,3]. Thus, reduction of child mortality, a central Millennium Development Goal (MDG) [4], remains an enormous challenge despite recent initiatives [5,6].

The WHO Commission on Macroeconomics and Health [6] concluded that health gains in low- and middle-income countries will result from increased spending within the health sector, through more international assistance, and through redistribution within national budgets. Recent reviews show that more investments in health systems can reduce child mortality if services are delivered effectively [7–10].

However, the major causes of child deaths [1] (malaria, HIV/AIDS, respiratory infections, gastro-intestinal infections, and measles) are also indirectly

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preventable though socioeconomic progress affecting nutrition, housing, hygiene, education, gender equality, and human rights.

While the major direct causes of child deaths are well known [3], our knowledge of the relative importance of underlying or distal socioeconomic determinants is less clear [11]. For example, the association between female literacy and health [12–14] is hardly controversial but it is not known whether it is the reading skills per se or other immeasurable effects of increased gender equality that contribute most to child survival.

Although gross national income per capita (GNI/capita) is clearly associated with IMR (Figure 1), this fact does not provide policy-makers with guidance on how most efficiently to reduce mortality at any given level of development. In a study of 22 low-income countries, Anand & Ravallion found that GNI/capita was a non-significant predictor of health when poverty rate and public spending on health had been accounted for [15]. In contrast, Filmer & Pritchett's study of 100 countries showed no significant correlation between public spending on health and IMR after controlling for gross domestic product per capita (GDP/capita) [12]. It has been suggested that income equality is more important for health than is absolute national income (GNI/capita or GDP/capita), and increasingly so when countries grow richer [16,17]. However, this has mainly been studied in high-income countries [18]. The degree to which different socioeconomic factors impact on infant survival across national economic levels is unclear and the relative importance of improved education, health services, and economic inequity may also vary between high-, middle-, and low-income countries. Also, the question whether health strategies from high-income countries could or should be extrapolated to middle- and low-income countries is rarely addressed.

Aim

In this study, we aimed to assess the strength of association between infant mortality rate (IMR) and five major socioeconomic determinants (GNI/capita, young female illiteracy, income equality, public spending on health, and poverty rate), using the international data available [2]. Our analyses include 152 countries, stratified by national (low-, middle-, and high-) income level.

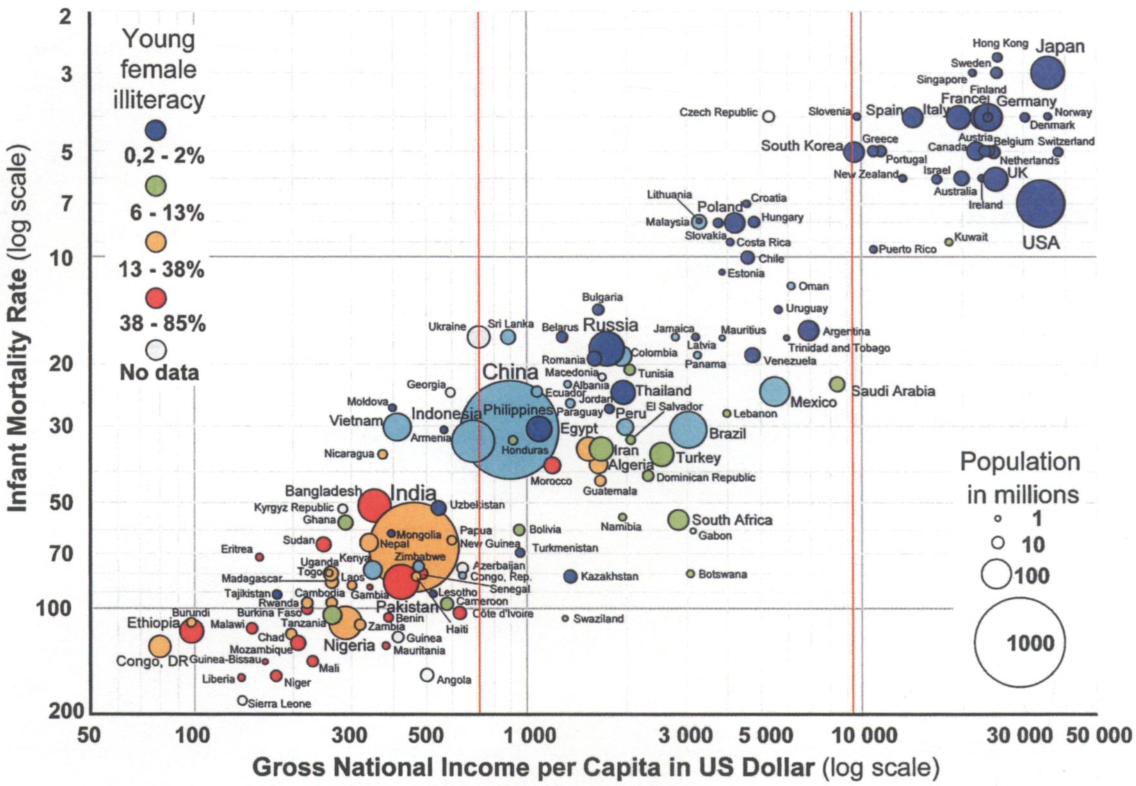

Figure 1. Infant mortality rate (IMR) by GNI/capita in US$ (both variables are on a logarithmic scale). Colour by young female illiteracy levels and size by population.

Material and methods

Study design and selection of variables

To analyse the relationship between major distal socioeconomic determinants and infant mortality rate (IMR: the number of infant deaths before one year of age per 1,000 live births) we used countries as units of observation. Estimates of IMR, under-five mortality rate (U5MR), and life expectancy (LE) are the most common proxy variables for measuring population health. We chose IMR as our main estimate of health since data on IMR are available for almost all countries and are highly correlated to the other health outcomes [19,20].

Infant or child deaths are seen as attributable to a range of hierarchical determinants (Figure 2) that may be *proximal* (e.g. infections and accidents), *intermediate* (e.g. electricity and sanitation), or *distal* (e.g. societal conditions measured in terms of socioeconomic achievements) (Figure 2) [11]. To assess the separate effects of each determinant we used multivariate regression models controlling for confounding. Based on the existing literature [15,16,21–23], we selected five potentially important socioeconomic factors that we conceptualized to be at the same distal hierarchical level [24] (Figure 2): We chose *GNI/capita in US$* (Atlas method [2]) as the measure of national income since it is more strongly correlated to IMR than estimates of GDP/capita or Purchasing Power Parity (PPP). As an estimate of health expenditure, we chose *Public spending on health (in current US$ per capita)* since our initial analyses showed that this variable was more highly correlated to all common health outcomes (IMR, U5MR and LE) than "Total spending on health" or "Private spending on health". We used *Young female illiteracy rate* (the percentage of women aged 15–24 who are illiterate) as an estimate of mothers' education and gender equality. Using illiteracy rather than literacy rates gave a higher correlation with IMR (on the log scale). To measure economic inequity, we selected the *Gini index* (the lower the Gini index, the more equal the distribution of wealth), which captures inequity in all income segments but is most sensitive to differences between the middle class and the very rich. As an estimate of absolute poverty, we used *Poverty rate*, defined as the proportion of the population living on less than US$1 per day, expressed in PPP since this measure is sensitive to the economic situation of the most unprivileged.

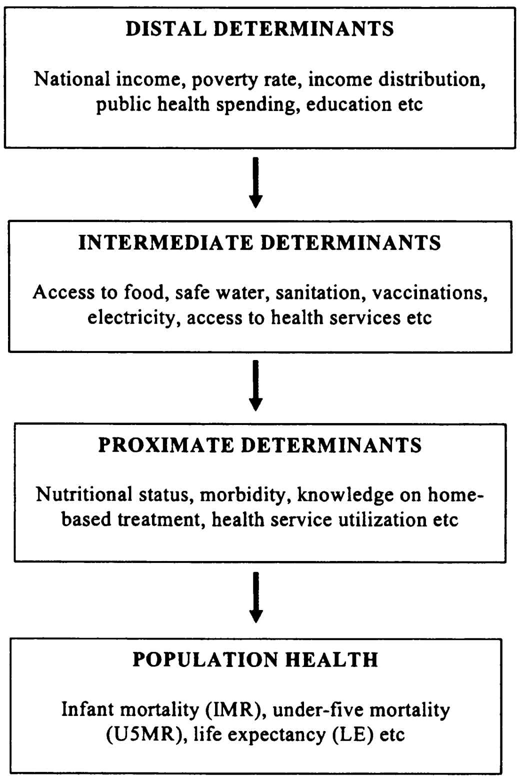

Figure 2. Conceptual framework of the hierarchy determining population health. This study assesses only relationships with distal determinants.

Data

The data set is mainly compiled from national data for 208 countries in the "World Development Indicators (WDI) 2003" [2]. Of 208 countries, 56 with a population less than 1 million inhabitants were excluded because most of these countries are small islands or city nations with special sociopolitical contexts and/or with incomplete data. The remaining 152 countries all had data on IMR and were included in the analyses. Table I shows the availability of data from countries grouped by income level, defined by the World Bank cut-offs for GNI/capita (low-income ⩽US$735, middle-income US$736–9,075, high-income countries⩾US$9,076) [2]. When poverty rate and young female illiteracy rate reached minimum threshold levels, no exact figures were reported by the World Bank [2]. Thus, in order to include these high-income countries in our analyses, we replaced poverty rates registered as "<2%" with "1%" in 25 countries and in 17 high-income countries where young female illiteracy rates were registered as "<0.2%" by the World Bank, we used "0.2%". For high-income countries with missing data on poverty and illiteracy we assumed that the minimum thresholds had been reached and ascribed these countries imputed minimum estimates, i.e. 1% and 0.2% respectively. In addition to the WDI 2003 data set,

Table I. Median (range) for each variable for all countries and stratified by income group.

	Income group				Missing data	
Variable	All[a]	Low	Middle	High[a]	Country or region with missing data	Median (range) of IMR in countries with missing data
Infant Mortality Rate (/1,000 live births)	31 (3–182)	86	22	5		
Number of countries	152	60	64	28		
National Income (US$/capita)	1,350 (80–38,330)	330	2040	22,790	Middle East (2)	77 (7–165)
Number of countries	145	56	61	28	Afghanistan Cuba, Somalia Myanmar, North Korea	
Young female illiteracy (% of age 15–24)	3 (0.2–86)[b]	28	3	0.2[b]	Post–USSR (3), Balkan (2)	56 (4–182)
Number of countries	138[b]	51	59	28[b]	Sub–Saharan Africa (5) Czech Republic West Bank &Gaza North Korea, Afghanistan	
Gini index	38 (24–63)	40	42	33	Balkan (3), Caribbean (3)	49 (7–165)
Number of countries	118	45	47	26	Middle East (9) South East Asia (3) sub-Saharan Africa (14) Argentina, Afghanistan	
Poverty rate (% with <1 US$ per day)	5 (1–82)[c]	36	2	1[c]	Balkan (3), Caribbean (3)	70 (7–165)
Number of countries	117[c]	41	48	28[c]	Middle East (7) South East Asia (5) sub-Saharan Africa (15) Argentina, Afghanistan	
Public spending on health (US$/capita)	41 (2–2,413)	6	79	1283		30 (10–66)
Number of countries	149	58	63	28	Nepal, Puerto Rico, Vietnam	

[a]In high-income countries some data were imputed; see following footnotes and methods section. [b]Without imputed data: n=125, median=5.5 (0.2–86). In high-income countries: n=11, median=0.2. [c]Without imputed data: n=92, median=13 (1–82). In high-income countries: n=3 (all reporting <2%).

we received young female illiteracy rates for Bosnia-Herzegovina, the Seychelles, Slovak Republic, and Turkmenistan from UNESCO [25].

Statistical analyses

After the initial selection of variables described above, a four-step procedure was performed to investigate the relative importance of the five predictor variables:

1. A visual analysis of scatter plots of IMR versus each predictor variable (Figure 3) was followed by mathematical transformations of the variables to find the best linear model, defined by the highest absolute value of the Pearson correlation coefficient.
2. Linear regression analyses were performed to examine all possible combinations of the five predictor variables, using adjusted R^2 as a measure of model strength. Models that included statistically non-significant ($p>0.05$) variables were considered inappropriate. The relative importance of each individual variable was assessed by its partial correlation.
3. Residual analysis was used to reveal outliers and to generate hypotheses for better models.
4. To investigate effect modification by income level, we fitted the models separately for low-, middle-, and high-income countries.

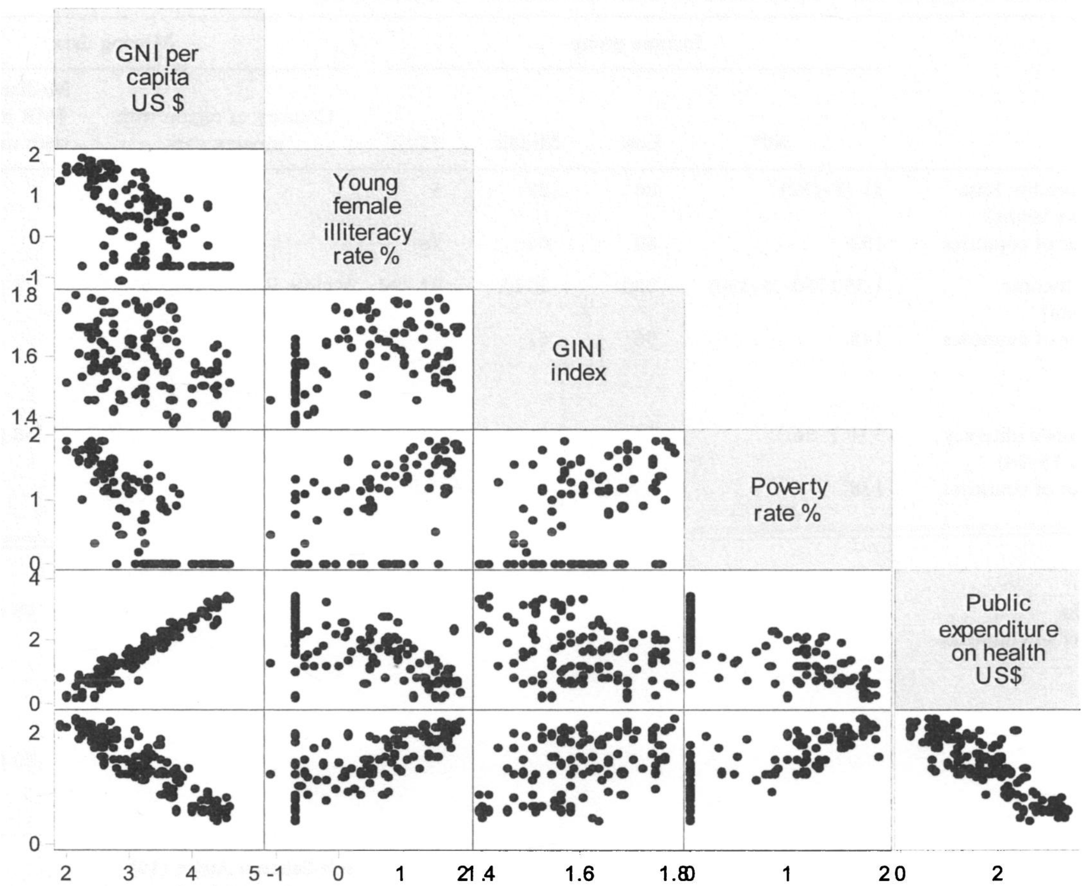

Figure 3. Scatter-plot matrix for all studied variables. The bottom row illustrates the correlation between the five predictor variables and IMR, while the other plots show the relationships between pairs of predictors.

The SPSS 10.0 statistical package [26] was used for all statistical analyses, with the exception of the graphical displays, which were produced using Stata version 8.0 [27] and World Health Chart [28].

Results

In summary, we found that a set of three socio-economic variables predicted 92% of national IMR at the global level. GNI/capita was the strongest independent predictor of IMR, followed by young female illiteracy rate and income distribution (Gini index). In stratified analyses, young female illiteracy was the most important independent predictor in low-income countries but also an important predictor in middle-income countries. Public spending on health did not make any significant contribution to IMR at any income level when adjusted for confounding from the above-mentioned variables.

All 152 countries

We explored the association between IMR and the predictor variables in univariate analyses (Table II) and in a scatter-plot matrix of pair-wise correlations between all five predictor variables and IMR (see Figure 3). For each individual predictor variable the best linear relationship with IMR was obtained when both IMR and the predictor variable were logarithmically transformed. This implies that a *relative* change (x%) in the predictor variable would result in a corresponding *relative* change (y%) in IMR. In univariate analyses, we found that IMR was strongly negatively correlated with both public spending on health ($r = -0.87$) and GNI/capita ($r = -0.91$) (see Figure 3, bottom row). However, when these two predictors were entered into the same multivariate model, only GNI/capita remained significant, implying that when GNI/capita is known, available numeric information on gross public spending on health does not contribute any additional information to the variation in infant mortality.

Table II: Correlations from univariate and multivariate regression models, predicting infant mortality rate (IMR) in all countries as well as in countries stratified by level of income (all variables are on the logarithmic scale).

	All countries[a]			Low-income countries[a]		Middle-income countries[a]		High-income countries[ab]
Predictor variables	Univariate	Multivariate		Univariate	Multivariate	Univariate	Multivariate	Univariate
GNI/capita								
Pearson/partial correlation	−0.91	−0.48	−0.85	−0.56	−0.46	−0.49	−0.56	−0.19.
Significance	$p<0.001$	$p<0.001$	$p<0.001$	$p<0.001$	$p=0.001$	$p<0.001$	$p<0.001$	$p=0.32$
Countries (n)	144	105	110	56	50	60	44	28
Young female illiteracy								
Pearson/partial correlation	0.82	0.46	0.45	0.65	0.55	0.65	0.36	NA
Significance	$p<0.001$	$p<0.001$	$p<0.001$	$p<0.001$	$p<0.001$	$p<0.001$	$p=0.018$	
Countries (n)	137	105	110	51	50	58	44	
Gini index								
Pearson/partial correlation	0.51	0.20	0.28	0.45	–	0.52	0.35	0.24
Significance	$p<0.001$	$p=0.042$	$p=0.003$	$p=0.002$		$p<0.001$	$p=0.024$	$p=0.244$
Countries (n)	117	105	110	45		46	44	26
Poverty rate								
Pearson/partial correlation	0.82	0.07	–	0.61	–	0.46	–	NA
Significance	$p<0.001$	$p=0.472$		$p<0.001$		$p=0.001$		
Countries (n)	116	105		41		47		
Public spending on health								
Pearson/partial correlation	−0.87	−0.03	–	−0.36	–	−0.35	–	−0.03
Significance	$p<0.001$	$p=0.767$		$p=0.006$		$p=0.005$		$p=0.900$
Countries (n)	148	105		58		62		28
Explained variation[c]		92%	92%		55%		62%	
Adjusted R^2		0.91	0.91		0.53		0.59	

[a]Number of countries with published data on this variable. Compared with the number of countries presented in Table I, one country, Kazakhstan, has been excluded due to being an extreme outlier in regression analyses. [b]No multivariate model is shown since there were no significant univariate correlations for variables with sufficient data fit analysis. [c]R^2 value. In determining model strength, *adjusted* R^2 was used to compensate for the number of variables. NA=not applicable in high-income countries, since reported values were constant for absolute poverty rate and young female illiteracy (with few exceptions). – Variable not included in the displayed multivariate regression model.

Poverty rate was strongly positively correlated with infant mortality (r=0.82) in univariate analyses but this relationship may be confounded by the poverty rate's high correlation with GNI/capita (Pearson r=0.80) and young female illiteracy (r=0.70) (see Figure 3). The importance of poverty rate in predicting IMR was very much reduced when GNI/capita and young female illiteracy were added in a multivariate regression model, and after adjustments for income distribution (Gini index), poverty rate became non-significant.

The best multivariate model predicted 92% of the variation in infant mortality and included GNI/capita, young female illiteracy rate and Gini index. GNI/capita was the strongest predictor of IMR overall, both in univariate analysis (r=−0.91) and in the best multivariate model, where its partial correlation was only slightly reduced (r=0.85) (Table II).

Young female illiteracy remained significant as a major contributor to the prediction of infant mortality in all possible models. When GNI/capita was controlled for, the partial correlation of young female illiteracy dropped from (r=0.82) to (r=0.55) and when the Gini index was added, it was reduced to (r=0.45), indicating that the variables for income inequality (Gini index) and young female illiteracy may represent some similar processes associated with infant mortality (see Table II). Gini-index per se made a small but significant contribution to the prediction of IMR (r=0.28) when adjusted for confounding by the other determinants.

To check validity, we repeated our analyses without any of the imputed illiteracy rates and poverty rates in high-income countries. The findings were not altered, and the same best model was identified with the partial correlations changing only marginally. Similar results were obtained when only countries that had data on all variables were included in the analyses (n=106). In residual plots, Kazakhstan was observed to be an extreme outlier, with an IMR much higher than predicted by the models, and we therefore removed this observation from further analyses.

Our models gave slightly different results when we used U5MR as a measure of health instead of IMR. With LE as the health outcome, GNI/capita remained the strongest predictor, and young female illiteracy the second strongest, although the importance of the latter was slightly lower for both U5MR and LE compared with when IMR was the dependent variable. Poverty rate rather than the Gini index was the third most important predictor of health measured as U5MR while public spending on health remained non-significant regardless of whether IMR, U5MR, or LE was used as the measure of health.

Stratified analyses in low-, middle- and high-income countries

In low-income countries, young female illiteracy was the strongest predictor of infant mortality, and remained so even when adjusted for GNI/capita (see Table II). The strong univariate correlation between infant mortality and poverty rate, and the weaker univariate correlations with public spending on health and Gini index, made no significant contribution in the multivariate model that adjusted for GNI/capita and young female illiteracy.

Also in middle-income countries, young female illiteracy was the strongest univariate predictor of infant mortality. However, the best multivariate model in these countries also included GNI/capita and the Gini index, with GNI/capita being more important than illiteracy rate (see Table II). When low- and middle-income countries were analysed together (n=84), we identified the same predictor variables as for the middle-income countries alone, and the model fit was very good (adjusted R^2=0.82).

In high-income countries we found no significant associations between socioeconomic predictors and IMR (see Table II, last column). We did not examine young female illiteracy or poverty rate, as there were no high-income countries with poverty above the 1% threshold and only three countries with illiteracy rates above the 0.2% threshold. We noted, however, that Kuwait and the United Arab Emirates, the two high-income countries with the highest young female illiteracy rates, also had the highest IMR, whereas GNI/capita for these countries was only slightly below the median. When we adjusted for other health outcomes, we found significant univariate correlations between the Gini index and U5MR and between GNI/capita and LE in high-income countries.

Discussion

Absolute wealth (GNI/capita) was the best predictor among all distal determinants of health that we considered. In a study of 60 low- and middle-income countries, Wang [29] found that intermediate and proximate level determinants such as immunization rate, knowledge of oral rehydration therapy, access to sanitation, and electricity had stronger correlations with child mortality than GNI/capita. However, when variables in the same causal chain are introduced into a multivariate model , the correlation of more distal determinants (see Figure 2) will be deceptively reduced in relation to more proximal ones [24], a phenomenon known as "over-adjustment" in epidemiological analysis. In most countries, economic growth enables numerous public and private actions at the intermediate level (such as those mentioned above) with positive effects on population health. Therefore, we consider our findings to be consistent with those of Wang.

Our results indicate that in low- and middle income countries, crude socioeconomic variables such as GNI/capita, female illiteracy rate, and income distribution (Gini index) explain a large part of the variation in IMR. However, in countries that have reached a high level of income and education, further progress in these distal determinants seems to be less important for reduction of infant mortality. Thus, extrapolating hypotheses and transferring health policies between countries may be misleading.

Our finding that public spending on health is not related to any one of the readily available health outcomes (IMR, U5MR, or LE) at any development level after adjustment for GNI/capita needs to be considered in the light of recent international initiatives to expand funding for health sector programmes (e.g. the WHO Commission on Macroeconomics and Health [6] and the Global Fund [5]). Filmer & Pritchett [12], who arrived at the same result, pointed out that publicly financed health interventions are inefficient unless disseminated through cost-effective health services that are used by the target population [12]. Intermediate or proximal-level (see Figure 2) investments in the health sector specifically targeted at the poor can be efficient in terms of reducing child mortality in the world [8] but, ironically, privileged urban populations often benefit more from public spending on health than those most in need [10]. As indicated by the *Lancet* series on child survival [7–10], health system investments must be evidence-based and use contextually sustainable and culturally sensitive forms of service delivery, not least with adequate numbers and financing of human resources for health. The financing and function of the general health service is today the most crucial barrier to scaling up access to, for example, antiretroviral drugs in sub-Saharan Africa [30]. Anand & Bäringhausen [20] showed that human resources for health were an important determinant of infant mortality even when controlling for national income, poverty, and female literacy. Public spending on health, however, seems an inadequate proxy for the quality of health services.

The importance of female illiteracy rates in our models suggests that investing in female education might be a rational intervention to prevent avoidable infant deaths in both low- and middle-income countries and possibly also in high-income countries with large gender disparities. For female illiteracy, we found stronger correlations with IMR than with LE as health outcome, which could support the common view of women as vectors of basic health skills, and explain why female (rather than overall) illiteracy is more associated with child health [31]. However, a literate woman who lacks influence cannot exert her knowledge. Our finding that female *illiteracy* correlates better to IMR than *literacy* rate (using logarithmic scales) is more than an academic exercise. It implies, perhaps against common prejudice, that a reduction in illiteracy from 10% to 5% is equally important as a reduction from 40% to 20%. Societies where it matters that *all* women are literate are probably more likely to emphasize gender equality. Previous research has shown that a woman's control over household resources has a significant effect on pre- and perinatal healthcare usage [32] and that child survival is higher in countries where female representation in politics is high [33].

Poverty reduction, the first MDG [4], is also the most difficult one to assess. Thus, the fact that we did not find a significant correlation between poverty rate and IMR after adjustments for young female illiteracy, GNI/capita, and Gini index does not challenge the obvious fact supported by micro-level studies [23,34–36], that individual poverty is clearly linked to infant morbidity and mortality. Instead, our finding underlines the importance of gender and social equality in education. For countries at the same GNI/capita level, a low absolute poverty rate does not seem to compensate for the fatal consequences associated with a high percentage of illiterate women.

Unequal income distribution (high Gini index) was a significant determinant of IMR on the global level after adjustment for confounding. Interestingly, in middle-income countries, this effect was as strong as that of female illiteracy rate (see Table II). Thus, our results suggest that income equality may be especially important in middle-income countries. Previous research has shown a continuously increasing importance of income equality for health as countries grow richer [16,17]. Whether the impact of equality on health is due to absolute or relative income effects or whether a low Gini index is a proxy for welfare policies in general has been much debated and studies, mainly from high-income countries and Chile [37], arrive at conflicting results [18,23,38–40].

Data validity and precision may vary since both poverty rate and Gini-index estimates derive from Living Standards Measurement Surveys [2] that sometimes are difficult to perform in low-income countries. Our model underestimated the true IMR in some countries in Central Asia, where data quality may be questioned [41], but also in Southern Africa, where IMR is likely affected by HIV (20% of the U5MR in South Africa and over 40% in Botswana has been attributed to AIDS [42]). On the other hand, IMR was lower than predicted by our model in Malaysia and Sri Lanka, both countries recognized for their high-quality health systems.

The weaker fit in analyses stratified by income level was probably due to a reduced range of values and fewer country observations [14,15,17]. The relatively high completeness of the data set used in our analyses is achieved by the World Bank through modelling to fill information gaps. The United Nation's MDG [4] process will, hopefully, stimulate more valid health data in the future but today modelled data are often all that is available for international agencies that present aggregate global data on an annual basis.

Conclusions

Our study indicates that the available crude macro measurements of public health sector spending do not have an independent effect on health gains. This finding supports the growing awareness that, in order to reach the MDGs [4], more efficient health systems for service delivery are required [43], and without functioning health systems and adequate numbers of skilled human resources, the capacity to absorb funding aimed at vertical health programmes is limited in many low-income countries. Secondly, our results indicate that health strategies from high-income countries may not be applicable in poorer countries. Lastly, if assessments of investments for health are limited to the health sector only, potential health gains from investments in other sectors, may be neglected. Investing in female education might be the most rational intervention that countries can make to prevent avoidable infant deaths.

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