Governance matters: an ecological association between governance and child mortality

Ro-Ting Lin\textsuperscript{a}, Lung-Chang Chien\textsuperscript{b,c}, Ya-Mei Chen\textsuperscript{d} and Chang-Chuan Chan\textsuperscript{a,e,*}

\textsuperscript{a}Institute of Occupational Medicine and Industrial Hygiene, College of Public Health, National Taiwan University, Room 722, No. 17, Xuzhou Road, Taipei City 100, Taiwan; \textsuperscript{b}Division of Biostatistics, University of Texas School of Public Health at San Antonio Regional Campus, 7411 John Smith Road, Suite 1100, San Antonio, TX 78229, USA; \textsuperscript{c}Research to Advance Community Health Center, University of Texas Health Science Center at San Antonio Regional Campus, 7411 John Smith Road, Suite 1050, Room 505, San Antonio, TX 78229, USA; \textsuperscript{d}Institute of Health Policy and Management, College of Public Health, National Taiwan University, Room 633, No. 17, Xuzhou Road, Taipei City 100, Taiwan; \textsuperscript{e}Global Health Center, College of Public Health, National Taiwan University, Room 108, No. 17, Xuzhou Road, Taipei City 100, Taiwan

*Corresponding author: Tel: +886 2 3366 8094; E-mail: cccchan@ntu.edu.tw

Received 1 October 2013; revised 20 February 2014; accepted 21 February 2014

Background: Governance of a country may have widespread effects on the health of its population, yet little is known about the effect of governance on child mortality in a country that is undergoing urbanization, economic development, and disease control.

Methods: We obtained indicators of six dimensions of governance (perceptions of voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption) and national under-5 mortality rates for 149 countries between 1996 and 2010. We applied a semi-parametric generalized additive mixed model to examine associations after controlling for the effects of development factors (urbanization level and economy), disease control factors (hygienic conditions and vaccination rates), health expenditures, air quality, and time.

Results: Governance, development, and disease control showed clear inverse relations with the under-5 mortality rate ($p<0.001$). Per unit increases in governance, development, and disease control factors, the child mortality rate had a 0.901-, 0.823-, and 0.922-fold decrease, respectively, at fixed levels of the other two factors.

Conclusions: In the effort to reduce the global under-5 mortality rate, addressing a country’s need for better governance is as important as improvements in development and disease control.

Keywords: Child mortality, Governance, Social determinants, Urbanization, World health

Introduction

Governance, broadly defined as the process by which the authority of a country exercises government formation, sound policy making and effective policy implementation, is regarded as a crucial determinant of population health.\textsuperscript{1,2} The effect of governance on the health of a country’s population is determined by the government’s response to its citizens’ needs, its distribution of health-related program resources, and its management of social and environmental conditions such as economic development, food security and public education.\textsuperscript{3,4} Therefore, a country’s governance is viewed as a key factor in achieving the United Nations (UN) Millennium Development Goals (MDG).\textsuperscript{5,6} Historical and contemporary political analyses have shown that governments are key players in devising public policies on labor markets, welfare systems, and economic growth strategies.

Core capabilities of an effective government are protecting the population from violence, preventing bureaucratic corruption, and supplying and meeting needs for public goods and services.\textsuperscript{9} Effective governance entails high-quality public services and the ability to contribute effectively to population health without undue political influence.\textsuperscript{10} Hence, effective governance, together with greater investments in infrastructure related to health, can improve people’s daily living environment, quality of life, and health.\textsuperscript{11} In contrast, less effective governance will be unable to improve the key socioeconomic determinants needed to benefit population health.\textsuperscript{12} Poor governance i.e., abusing citizens, failing to provide equal protection under the law, or corrupting and mismanaging resources, infrastructure or the economy, is detrimental to population health.\textsuperscript{6}

There has been a growing quest for better governance in the pursuit of health equity at the global level.\textsuperscript{12} This issue is
particularly important as progress toward the MDG for child mortality has been slower than expected.6,13 Lozano et al. estimated that only 7% (9 out of 137) of developing countries were likely to meet the target child mortality rate by 2015.14 In 2010, global donors committed US$40 billion to accelerate progress toward this MDG.15 However, lack of effective governance was found to be a substantial risk factor, resulting in an inability to utilize aid resources and eventually in failure to institute a good healthcare system.16

Another concern has been the interplay between governance and population health in the context of the trend toward country-level urbanization and the pursuit of economic growth for better living and health conditions.3,10,17,18 People who live in urban settings or in countries with relatively better economic status are likely to have better access to food, sanitation, education, employment and healthcare - all factors that may contribute to better health.19 A failure of governance in the course of a country’s path toward urbanization and economic development can result in ineffective health policies and services, resulting in unhealthy living conditions such as informal urban settlements and slums.18,20 Such poor living conditions are usually associated with unsafe drinking water and lack of improved sanitation facilities, and may place people at risk of contracting easily preventable diseases.

Attention is also being paid to the role of governance in the practice of disease control, especially during the course of urbanization.21 Urbanization in the demographic sense is defined as the process of increasing the concentration of people living in urban areas. Moore notes that greater population density in urban settings is associated with greater potential for disease transmission and greater susceptibility to disease epidemics.22 Communicable and non-communicable chronic diseases alike, including malaria, HIV/AIDS, and illness related to air pollution, have been increasing dramatically in rapidly urbanizing areas of Africa and Asia, and in various countries in other parts of the world with relatively low per capita incomes.20,21,23 The crowding in high-density urban environments requires good urban governance for effective disease control.20

Children, as a result of physiological and behavioral differences from adults, are more susceptible to environmental, political, and socioeconomic factors.2,7,24,25 As global efforts toward reducing child mortality get under way, an understanding of how governance affects child health in the context of urbanization, economic development and disease control, especially in countries with poor governance, is essential. However, attempts to estimate the effect of governance on child mortality in the context of a country’s urbanization, economic development and disease control are generally hampered by a lack of comparable indicators across countries. In addition, yearly variability in all these factors, together with the continuous effect of governance indicators, is likely to lead to complications; longitudinal analysis should therefore be used.

We aimed to investigate how country-level child mortality is associated with urbanization, economic development, disease control, and governance. To address this issue, we collected publicly available country-specific data and conducted cross-national comparisons and longitudinal data modeling. The objective of our study was to investigate the ecological association between governance and child mortality and to provide global health efforts with further evidence of the need for better governance.

Materials and methods

Data sources

We obtained data on child health and its predictors, from publicly available databases, for the period 1996 to 2010 for 149 countries (representing 96.5% of the world’s population in 2010) that offered available data for analyses. The measure used to indicate child health status in each country was the under-5 mortality rate investigated in this study are shown in Box 1. Governance indicators were extracted from the Worldwide Governance Indicators (WGI) reported by the World Bank.1,26 The WGI, a database published by the World Bank in 1996, consists of six dimensions of governance: voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption.1 It was updated every 2 years between 1996 and 2002 and has been updated annually since 2002.1 The six governance indicators were aggregated from 441 indicators of 35 data sources for 212 countries and territories. These data were based on surveys of individuals or domestic firms with first-hand knowledge of the governance situation in the country to reflect the common perceptions of diverse data providers, including commercial businesses (averaged share of sources=31%), surveys of firms or households (27%), non-governmental organizations (16%), and the public sector (26%).1 The unobserved components model was applied to construct an aggregate of the six governance dimensions from these individual measures.1 Data were first rescaled and then averaged with weights based on the precision of the individual data sources for each of the governance indicators: commercial businesses (averaged share of weights=.37), surveys of firms or households (0.14), non-governmental organizations (0.22), and the public sector (0.28).1 To facilitate cross-country and over-time comparison, the scores were normally distributed, with a mean of zero and a standard deviation of one.1,27 With such transformation, the indicator acted as proxy of a country’s relative state of governance.27 These WGI scores were used to reflect relative levels of governance among studied countries, and do not directly quantify absolute qualities of governance.

Urbanization was measured as the proportion of a country’s population living in areas classified as urban, according to the criteria used by that country.25 We chose national economies for our analysis because poverty perpetuates inadequate living conditions and drives up child mortality.28 Population immunization rate (e.g. against measles, and diphtheria, pertussis, and tetanus [DPT]), clean water supply, and sanitation were also considered in our analysis because they are vital elements in preventing disease outbreaks. These data were obtained from the World Bank’s World Development Indicators and country reports. High population density with inadequate medical and hygienic services contributes to a rising incidence of communicable diseases in urban environments.28 The evidence on the effect of health expenditures on reducing child mortality is inconclusive: some studies have found a country’s health expenditures to have positive effects on population health outcomes,29,30 while others have
shown minor or non-significant effects on child mortality.31–33 For this study, we included health expenditures as a variable in our factor selection process. We also included air pollution, because it can reflect a country’s environmental quality during urbanization and industrialization34 and is associated with various adverse health effects for children, including increased hospital admissions for acute respiratory conditions, increased medication use in children with asthma, and mortality.35–37 The major sources of urban air pollution are burning of fossil fuels or biomass, power generation, industrial processes, and motor vehicle activities.38

### Data analysis

We first applied a factor analysis with a varimax rotation to reduce the number of correlated variables and identify and categorize interrelated variables.39 Factors with eigenvalues >1 were

---

**Box 1. Definition and source of the selected indicators of governance, development, and disease control**

**Voice and accountability**

Perceptions of the extent to which a country’s citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media1 (World Bank’s World Governance Indicators [WGI]).

**Political stability and absence of violence**

Perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically motivated violence and terrorism1 (World Bank’s WGI).

**Government effectiveness**

Perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government’s commitment to such policies1 (World Bank’s WGI).

**Regulatory quality**

Perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development1 (World Bank’s WGI).

**Rule of law**

Perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence1 (World Bank’s WGI).

**Control of corruption**

Perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as ‘capture’ of the state by elites and private interests1 (World Bank’s WGI).

**Urbanization**

Proportion of a country’s population living in areas classified as urban, according to the criteria used by each country (United Nations’ World Population Prospects, Ministry of the Interior of Taiwan).

**Economy**

The state of each country’s economy was calculated from income based on the yearly expenditure-side gross domestic product (GDP) at purchasing power parity (Penn World Table version 8.0).

**Immunization**

Proportion of children aged 12–23 months in each country who had received immunization against measles and against diphtheria, pertussis, and tetanus (DPT) (World Bank’s World Development Indicators [WDI], Department of Health of Taiwan).

**Clean water supply**

Proportion of the population in each country with access to an improved water source (World Bank’s WDI, Ministry of Economic Affairs of Taiwan).

**Sanitation**

Proportion of a country’s population with access to improved sanitation facilities (World Bank’s WDI, Ministry of the Interior of Taiwan).

**Health expenditures**

Sum of public and private health expenditures as a percentage of total GDP, which covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation (World Bank’s WDI, Social Indicators of Taiwan).

**Air quality**

Annual average concentrations of particulate matter with diameter <10 μm (PM10) (World Bank’s WDI, Environmental Protection Administration of Taiwan).

---

\(^{a}\) The World Bank collected the PM10 data from the WHO and then estimated the country-level PM10 data using urban-population-weighted PM10 levels in residential areas of cities larger than 100,000. For Taiwan, we used the average PM10 data collected from ambient air quality monitoring stations located in areas of high population density.
selected for further modeling. Next, the effects of selected factors on the under-5 mortality rate were analyzed using the semiparametric generalized additive mixed model, with the logarithm of the under-5 mortality rate \( (Y) \) to base 10 of a country as the dependent variable, selected factors \( (F_i) \) as fixed-effect variables, and the intercept as the random-effect variable:

\[
\log_{10} Y_{j,t} = \beta_0 + b_{0j} + \sum_{i} \beta_{ij} \times F_{i,j,t} + f(T) + \epsilon_{j,t}
\]

where \( i \in \{1, 2, 3, \ldots\} \) denotes the number of selected factors, \( j \in \{1, 2, \ldots, 149\} \) denotes the country code, and \( t \in \{1, 2, \ldots, 15\} \) denotes the calendar year from 1996 to 2010. The decision on whether to keep or drop factors \( (F_i) \) was based on the Akaike information criterion. The time smoother \( f(T) \) was estimated by a cubic B-spline to control temporally autoregressive correlations. \( \epsilon_{j,t} \) was the error term following a normal distribution with mean zero and variance \( \sigma_{\epsilon_{j,t}} \). The random intercept \( b_{0j} \) was an unstructured spatial term following a normal distribution with mean zero and estimated variance 0.1980 to control for spatial heterogeneity among countries. All parameters were derived by the maximum subject-specific pseudolikelihood.

All statistical analyses were performed by the PROC CORR, FACTOR, and GLIMMIX procedures in SAS V9.2 (SAS Institute, Cary, NC, USA). Graphs were drawn using SigmaPlot V10.0 (Systat Software, Richmond, CA, USA).

### Results

Table 1 shows the averaged means, standard deviations, minimums, and maximums for the under-5 mortality rate, the six governance indicators, and the other eight selected determinants of child mortality across 149 countries in 2010. On average, the difference in mortality rate between countries with the lowest and the highest rates was 89-fold, with the lowest rate being observed in Singapore (2.28 per 1000 live births) and the highest rate in Chad (202.89 per 1000 live births). The lowest governance scores were: voice and accountability (−2.02) and regulatory quality (−2.08) in Turkmenistan, political stability and absence of violence score (−2.73) in Pakistan, government effectiveness

| Indicators | Mean\(^a\) | SD | Minimum | Median | Maximum | Mode |
|-----------|-----------|----|---------|--------|---------|------|
| Under-5 mortality rate | 49.88 | 51.65 | 2.28 | 27.07 | 202.89 | - |
| Governance indicators | | | | | | |
| Voice and accountability score (points) | -0.10 | 0.97 | -2.02 | -0.14 | 1.61 | - |
| Political stability and absence of violence score (points) | -0.19 | 0.92 | -2.73 | -0.06 | 1.44 | - |
| Government effectiveness score (points) | -0.02 | 0.99 | -1.73 | -0.21 | 2.24 | - |
| Regulatory quality score (points) | 0.01 | 0.94 | -2.08 | -0.15 | 1.90 | - |
| Rule of law score (points) | -0.11 | 0.99 | -1.79 | -0.36 | 1.97 | - |
| Control of corruption score (points) | -0.09 | 1.01 | -1.50 | -0.39 | 2.38 | - |
| Development related indicators | | | | | | |
| Urbanization level (% of a country’s population living in urban areas) | 55.99 | 22.15 | 11.00 | 58.15 | 100.00 | 40.10 |
| Log transformed expenditure-based GDP at purchasing power parity (millions of international dollars) | 10.99 | 2.05 | 5.66 | 10.90 | 16.39 | - |
| Disease control-related indicators | | | | | | |
| Clean water supply (% of population with access to an improved water source) | 86.82 | 15.68 | 44.00 | 93.00 | 100.00 | 100.00 |
| Sanitation (% of population with access to improved sanitation facilities) | 70.94 | 30.44 | 9.00 | 83.00 | 100.00 | 100.00 |
| Immunization: measles (% of children ages 12–23 months immunized against measles) | 87.68 | 13.15 | 33.00 | 93.00 | 99.00 | 99.00 |
| Immunization: DPT (% of children aged 12–23 months immunized against DPT) | 88.38 | 13.37 | 33.00 | 94.00 | 99.00 | 99.00 |
| Health expenditure-related indicators | | | | | | |
| Health expenditures, total (% of GDP) | 6.91 | 2.89 | 0.68 | 6.48 | 20.80 | 4.39 |
| Pollution-related indicator | 36.50 | 25.17 | 6.00 | 29.00 | 137.00 | 27.00 |

SD: standard deviation; GDP: gross domestic product; DPT: diphtheria, pertussis, and tetanus; PM\(_{10}\): particulate matter with diameter <10 \( \mu \). ^a Values were estimated using the latest available data for each country. All data were from 2010 with the following exceptions: clean water supply data for Argentina (2007), Equatorial Guinea (2006), Grenada (2004), Lithuania (2009), Panama (2009), Romania (2008), Tunisia (2009), Turkmenistan (2006), and Venezuela (Bolivarian Republic of) (2007); sanitation data for Argentina (2007), Equatorial Guinea (2006), Lebanon (2005), Latvia (2009), Lithuania (2009), Panama (2009), Romania (2008), Tunisia (2009), and Venezuela (Bolivarian Republic of) (2007); and health expenditure data for Zimbabwe (2001).
(–1.73) in Comoros, rule of law (–1.79) in Zimbabwe, and control of corruption (–1.50) in Equatorial Guinea. Most of the highest governance indicator scores were observed in European countries, including voice and accountability (1.61) in Switzerland, political stability and absence of violence (1.44) in Luxembourg, rule of law (1.97) in Finland, and regulatory quality (1.90) and control of corruption (2.38) in Denmark; the highest government effectiveness score was observed in Singapore (2.24).

Scatter plots of 2010 national data for the under-5 mortality rate, associated with the six governance indicators, are shown in Figure 1. All six dimensions of governance show inversely linear relations with the under-5 mortality rate.

Figure 1. Ecological relations between national under-5 mortality rate (deaths at age <5 years per 1000 live births) and the World Bank's six Worldwide Governance Indicators across 149 countries in 2010. (A) Voice and accountability; (B) political stability and absence of violence; (C) government effectiveness; (D) regulatory quality; (E) rule of law; (F) control of corruption.

| Variable                            | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|-------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|
| (1) Voice and accountability        | 1   | 0.68| 0.83| 0.86| 0.84| 0.81| 0.48| 0.31| 0.56| 0.47  | 0.39 | 0.43 | 0.50 | –0.36|
| (2) Political stability and absence of violence | 0.68| 1   | 0.72| 0.69| 0.78| 0.74| 0.43| 0.09| 0.49| 0.46  | 0.43 | 0.46 | 0.29 | –0.35|
| (3) Government effectiveness       | 0.83| 0.72| 1   | 0.93| 0.95| 0.94| 0.58| 0.49| 0.64| 0.60  | 0.46 | 0.50 | 0.41 | –0.36|
| (4) Regulatory quality              | 0.86| 0.69| 0.93| 1   | 0.92| 0.88| 0.55| 0.44| 0.60| 0.57  | 0.45 | 0.49 | 0.41 | –0.37|
| (5) Rule of law                     | 0.84| 0.78| 0.95| 0.92| 1   | 0.95| 0.54| 0.40| 0.61| 0.57  | 0.45 | 0.49 | 0.42 | –0.34|
| (6) Control of corruption           | 0.81| 0.74| 0.94| 0.88| 0.95| 1   | 0.55| 0.37| 0.57| 0.54  | 0.40 | 0.45 | 0.45 | –0.34|
| (7) Urbanization                    | 0.48| 0.43| 0.58| 0.55| 0.54| 0.55| 1   | 0.46| 0.65| 0.63  | 0.42 | 0.39 | 0.29 | –0.28|
| (8) Economy\(^{a}\)                 | 0.31| 0.09| 0.49| 0.44| 0.40| 0.37| 0.46| 1   | 0.42| 0.42  | 0.32 | 0.29 | 0.17 | –0.10|
| (9) Clean water supply              | 0.56| 0.49| 0.64| 0.60| 0.61| 0.57| 0.65| 0.42| 1   | 0.80  | 0.69 | 0.70 | 0.28 | –0.38|
| (10) Sanitation                     | 0.47| 0.46| 0.60| 0.57| 0.57| 0.54| 0.63| 0.42| 0.80| 1     | 0.69 | 0.67 | 0.27 | –0.35|
| (11) Immunization: measles          | 0.39| 0.43| 0.46| 0.45| 0.45| 0.40| 0.42| 0.32| 0.69| 0.69  | 1    | 0.92 | 0.22 | –0.32|
| (12) Immunization: DPT              | 0.43| 0.46| 0.50| 0.49| 0.49| 0.45| 0.39| 0.29| 0.70| 0.67  | 0.92 | 1    | 0.25 | –0.33|
| (13) Health expenditures            | 0.50| 0.29| 0.41| 0.41| 0.42| 0.45| 0.29| 0.17| 0.28| 0.27  | 0.22 | 0.25 | 1    | –0.31|
| (14) PM\(^{10}\)                    | −0.36| −0.35| −0.36| −0.37| −0.34| −0.34| −0.28| −0.10| −0.38| −0.35  | −0.32| −0.33| −0.31| 1    |

DPT: diphtheria, pertussis, and tetanus; PM\(^{10}\): particulate matter with diameter <10 μ. p-values for all correlations <0.001.

Economy indicator was log transformed.
Table 2 shows the correlation among the predictors. All of these predictors are significantly correlated, with p-values of <0.001. High correlations are observed between the governance indicators (Pearson’s correlation coefficient, \( r = 0.68–0.95, p < 0.001 \)); between clean water supply and sanitation (\( r = 0.80, p < 0.001 \)); and between immunization against measles and DPT (\( r = 0.92, p < 0.001 \)).

Table 3 shows three factors with eigenvalues >1 and thus qualified for further modeling. The cumulative variance explained by these three factors reached 76.38%. The six WGI showed the largest loadings for factor 1, named ‘governance’. The relative contributions of the six indicators towards governance, ranked from high to low, were rule of law, control of corruption, government effectiveness, regulatory quality, political stability and absence of violence, and voice and accountability. Hygienic conditions, including clean water supply and sanitation, and immunization rate against measles and DPT had the largest loadings for factor 2, named ‘disease control’. The relative contributions of the four disease-control factors, ranked from high to low, were immunization against measles, immunization against DPT, clean water supply, and sanitation. Urbanization and economy showed the largest loadings for factor 3, named ‘development’. Economy showed a higher contribution to development than urbanization.

Table 4 lists the influence of the three qualifying factors on under-5 mortality rates. All three factors were inversely associated with the log-transformed mortality rates (\( p < 0.001 \)). The coefficients suggest that, per unit increases in governance, disease control, and development, the child mortality rate had a 0.901-fold (\( 10^{-0.0453} \) (95% CI 0.877–0.926), 0.922-fold (\( 10^{-0.0351} \) (95% CI 0.903–0.942), and 0.823-fold (\( 10^{-0.0846} \) (95% CI 0.791–0.857) decrease, respectively, at fixed levels of other two factors.

Table 3. Factor loading matrix for the major factors affecting population health across 149 countries

| Determinants                  | Factor 1 (Governance) | Factor 2 (Disease control) | Factor 3 (Development) |
|-------------------------------|-----------------------|---------------------------|------------------------|
| (1) Voice and accountability  | 0.8224 *              | 0.1823                    | 0.1557                 |
| (2) Political stability        | 0.8258 *              | 0.3040                    | -0.1253                |
| (3) Government effect          | 0.8630 *              | 0.2429                    | 0.3400                 |
| (4) Regulatory quality         | 0.8491 *              | 0.2344                    | 0.2976                 |
| (5) Rule of law                | 0.9035 *              | 0.2435                    | 0.2378                 |
| (6) Control of corruption      | 0.8942 *              | 0.1855                    | 0.2363                 |
| (7) Urbanization               | 0.3999                | 0.2700                    | 0.6174 *               |
| (8) Economy                   | 0.1558                | 0.1469                    | 0.8708 *               |
| (9) Clean water supply         | 0.3836                | 0.6576 *                  | 0.4081                 |
| (10) Sanitation                | 0.3451                | 0.6434 *                  | 0.4630                 |
| (11) Immunization: measles     | 0.1904                | 0.9305 *                  | 0.1225                 |
| (12) Immunization: DPT         | 0.2544                | 0.9188 *                  | 0.0670                 |
| (13) Health expenditures       | 0.2925                | 0.1007                    | 0.0810                 |
| (14) PM10                      | -0.2116               | -0.1713                   | -0.0263                |

DPT: diphtheria, pertussis, and tetanus; PM10: particulate matter with diameter <10 μ.

* Factor loading >0.5.

^ The economy indicator was log transformed.

Table 4. Estimated fixed effects of determinants on under-5 mortality rates at the country level

| Determinants                  | Coefficients (95% CI) |
|-------------------------------|-----------------------|
| Intercept                     | 1.4067 (1.2985 to 1.5150) |
| Governance (Factor 1)         | -0.0453 (-0.0569 to -0.0336) |
| Disease control (Factor 2)    | -0.0351 (-0.0443 to -0.0258) |
| Development (Factor 3)        | -0.0846 (-0.1020 to -0.0672) |

^ Estimated using a semi-parametric generalized additive mixed model for data from 149 countries from 1996 to 2010.

^ Factors were derived from factor analysis. Factor 1, named ‘governance’, was related to the six Worldwide Governance Indicators (i.e. voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption). Factor 2, named ‘disease control’, was related to hygienic condition (i.e. clean water supply and sanitation) and immunization rate against measles and DPT. Factor 3, named ‘development’, was related to urbanization and economy (in log transformation).

Discussion

This study contributes to our understanding of global child health issues by showing the significant association between governance and under-5 mortality rates at country level, taking into account factors of development (mainly urbanization and economy) and disease control (mainly hygienic conditions and immunization rates). As the difference in child mortality rates between countries
remained as high as 89-fold in 2010, our results indicate that the effect of governance on child mortality is just as important as the effect of development and disease control. Per unit increases in governance, disease control and development could contribute to a 0.901-, 0.922-, and 0.823-fold decrease, respectively, in under-5 mortality rates at fixed levels of the other two factors. Our model predicted best for Taiwan, Uganda, Philippines, Slovakia, and Norway, and worst for Equatorial Guinea, Nepal, Luxembourg, Oman, and the Maldives.

Improvements in a country’s level of development (mainly urbanization and economy) have always been the primary factors for reductions in the under-5 mortality rate. The contribution of urbanization to better health could be associated with economic development. However, the recent economic downturn has threatened positive health outcomes in many countries by affecting food prices and increasing nutrition deficiencies. Our results suggest that even if a country has not benefited from urbanization or economic growth, the plausible positive role of better access to improved social and environmental conditions, enabled under effective governance, might be an alternative for a country pursuing reductions in its child mortality rate. These results are especially useful in the context of the current global economic crisis.

Immunization rate against measles increased from 79.5% to 87.7% and that against DPT increased from 79.7% to 88.4%, for the studied 149 countries from 1996 to 2010. The increased delivery of immunization services by domestic and international efforts, such as the Global Alliance for Vaccines and Immunization and the Global Fund to Fight AIDS, TB and Malaria, lowered child mortality rates in most countries.

There is a growing quest for better governance at both the country and global level in the pursuit of health equity. Our findings indicate that the association of governance with child mortality should not be underestimated. Governance represents the characteristics of the management of a social organization. From the viewpoint of a country, its governance consists of the traditions and institutions by which authority is exercised and the country is governed. According to the concepts developed by the World Bank, governance of a country represents: 1. the process by which the government is selected, monitored, and replaced; 2. the capacity of the government to effectively formulate and implement sound policies; 3. the respect of citizens and the state for the institutions that govern economic and social interactions among them. Experts have suggested that countries with better governance are likely to have health policies that benefit the social determinants of health. In contrast, poor governance might negatively impact health expenditures and health services for the general population. Corruption, or the misuse of public power for private gain, has been the most studied factor of governance in relation to its detrimental impact on the healthcare system, resource distribution, and health outcomes. A study on the progress of MDG 1, a program with the goal of eradicating extreme hunger and poverty, indicated that political decisions on government expenditures played a key part in meeting the MDG 1 goal in 88 countries. For example, poor-quality public administration and inefficient healthcare spending have been shown to have a negative impact on child health (including child mortality rates) in some Middle Eastern and African countries. Previous evidence has also indicated that around 5–10% of health-related budgets disappeared before they were spent on real practices. Anti-corruption efforts can be demonstrated to be a key component of good governance and even a reason to weaken countries off foreign aid.

Although corruption is recognized conceptually as an important driver of population health via its interaction with various socioeconomic determinants, there has been limited research on the effects of corruption on health that also considers the demographic factors of population growth and aggregation. These factors put direct pressure on health resource use, in addition to the interplay of governance (as defined by WGI) in this changing world. Our findings presented here consider the effect of a demographic factor (i.e. urbanization), and also incorporate governance, encompassing the concept of voice and accountability, political stability and absence of violence, government effectiveness, regulatory quality, rule of law, and control of corruption.

The use of a global and longitudinal dataset of under-5 mortality rates was necessary to understand the health impacts and potential applications of health policies and resolutions. To our knowledge, this is the first study to address the effects of governance on child mortality that uses longitudinal data and adjusts for the effect of time (i.e. calendar year), development factors (i.e. urbanization and economy), and disease control factors (i.e. clean water supply, sanitation, and measles and DPT vaccination rate) on a global scale. The inclusion of a large number of countries enhances data completeness. Our further analyses of removing the top five countries with lowest and highest governance scores indicated that association between governance and child mortality remained robust. However, our ecological dataset was limited to inter-country and not intra-country comparisons.

**Limitations**

Our findings should also be cautiously interpreted within the constraints of an ecological study. Important contributors to the total burden of child mortality, such as nutrition and intra-country inequality, warrant a framework that explores the causal pathways between child mortality and its determinants. For example, the distribution of the economy (e.g. Gini coefficient) and other determinants of health among different social groups within a country (e.g. urban–rural and intra-urban differences) also influence inequalities in health outcomes at the intra-country level. Because intra-country data on urban–rural health conditions and health risks were limited and incomplete, for this study we could not differentiate health impacts by urban–rural areas or by demographic characteristics, such as age and sex, within a country. Our model may therefore have overestimated the health of subpopulations with lower socioeconomic status, and this limitation should be taken into account in future studies.

Several other limitations should be noted. One limitation is potential confounding factors. A major challenge for ecological studies is the scarcity of comparable data. Estimates vary depending on how many potential confounding factors are controlled, how many countries are included, and over what span of time data are collected. For these reasons, we used the largest possible number of confounding factors to examine whether adding predictors as fixed effects would provide better model fitness. We may have overestimated the effects of significant determinants in our models by not fully considering these unmeasured factors, because of the scarcity of available data. However,
when we added confounding factors as fixed effects, our models showed the number of countries to drastically decrease. For example, the number of countries with data available decreased from 149 to 55 when we added literacy rate, nutritional status and Gini coefficient into our model. Therefore, we preferred to report the findings based on our current model, which had the largest number of studied countries and increased representativeness. In addition, we treated the country itself as the random effect to control for the effects of country heterogeneity, which would act as a proxy variable for these unmeasured factors. If more comparable and comprehensible data were available, we would expect a better estimation.

Conclusions

Governance should be taken into account in global health efforts to reduce the under-5 mortality rate in the context of global urbanization, economic growth, and disease control. Countries should target their efforts toward providing healthier physical and social living environments through better governance. Global health communities should start collecting useful information related to indicators of governance and initiate studies into the causal pathways between governance and important socioeconomic determinants of population health.

Authors’ contributions: R-TL and C-CC contributed to the study design; R-TL undertook the data collection; Y-MC assisted with the literature review and data interpretation; R-TL and L-CC contributed to the statistical analysis and interpretation of the data. All authors contributed to discussing content and writing this manuscript. All authors read and approved the final manuscript. R-TL and C-CC are guarantors of the paper.

Acknowledgements: We thank the editors at Tandem Editing for their careful copy-editing.

Funding: This work was supported by the National Science Council of Taiwan [grant numbers NSC 97-2314-B-002-075-MY3, NSC 97-2923-I-002-001-MY4].

Competing interests: None declared.

Ethical approval: Not required.

References

1 Kaufmann D, Kraay A, Mastruzzi M. Governance Matters VIII: Aggregate and Individual Governance Indicators, 1996–2008. World Bank Policy Research Working Paper No. 4978. Washington, DC, USA: The World Bank; 2009.
2 Burris SC. Governance, microgovernance and health. Temple Law Review 2004;77:335–62.
3 Guisan MC. Government effectiveness, education, economic development and well-being: analysis of European countries in comparison with the United States and Canada, 2000–2007. Appl Economet Int Dev 2009;9:30–55.
4 Sacks A, Levi M. Measuring government effectiveness and its consequences for social welfare in sub-Saharan African countries. Social Forces 2010;88:2325–51.
5 Siddiqi S, Masud TI, Nishtar S et al. Framework for assessing governance of the health system in developing countries: gateway to good governance. Health Policy 2009;90:13–25.
6 Sachs JD, McArthur JW. The Millennium Project: a plan for meeting the Millennium Development Goals. Lancet 2005;365:347–53.
7 Navarro V, Muntaner C, Borrell C et al. Politics and health outcomes. Lancet 2006;368:1033–7.
8 Kaufmann D, Kraay A. Governance indicators: where are we, where should we be going? World Bank Res Obsr 2008;23:1–30.
9 Levi M. Why we need a new theory of government. Perspectives on Politics 2006;4:5–19.
10 Kirigia JM, Kirigia DG. The essence of governance in health development. Int Arch Med 2011;4:11.
11 Kakwani N. Performance in living standards: an international comparison. J Dev Econ 1993;41:307–36.
12 Commission on Social Determinants of Health (CSDH). Closing the gap in a generation: health equity through action on the social determinants of health. Final report of the CSDH. Geneva, Switzerland: WHO; 2008.
13 Rajaratnam JK, Marcus JR, Flaxman AD et al. Neonatal, postneonatal, childhood, and under-5 mortality for 187 countries, 1970–2010: a systematic analysis of progress towards Millennium Development Goal 4. Lancet 2010;375:1988–2008.
14 Lozano R, Wang H, Foreman KJ et al. Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis. Lancet 2011;378:1139–65.
15 Global Strategy for Women’s and Children’s Health. Commitments Summary: 29 September 2010. http://www.who.int/pmnch/events/2010/commitments_summary092910.pdf [accessed 4 August 2013].
16 Israr SM, Islam A. Good governance and sustainability: a case study from Pakistan. Int J Health Plann Manage 2006;21:313–25.
17 Dye C. Health and urban living. Science 2008;319:766–9.
18 Burris S, Hancock T, Lin V et al. Emerging strategies for healthy urban governance. J Urban Health 2007;84(suppl 1):154–163.
19 Galea S, Vlahov D. Urban health: evidence, challenges, and directions. Annu Rev Public Health 2005;26:341–65.
20 Kjellstrom T, Mercado S. Towards action on social determinants for health equity in urban settings. Environ Urban 2008;20:551–74.
21 Leon DA. Cities, urbanization and health. Int J Epidemiol 2008;37:4–8.
22 Moore M, Gould P, Keary BS. Global urbanization and impact on health. Int J Hyg Environ Health 2003;206:269–78.
23 Hay SI, Guerra CA, Tatem AJ et al. Urbanization, malaria transmission and disease burden in Africa. Nat Rev Microbiol 2005;3:81–90.
24 Black RE, Allen LH, Bhatta ZA et al. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 2008;371:243–60.
25 United Nations. World Population Prospects: The 2010 Revision. http://esa.un.org/wpp/ [accessed 10 March 2012].
26 Kaufmann D, Kraay A, Mastruzzi M. The Worldwide Governance Indicators, 2011 Update. Aggregate Indicators of Governance 1996–2010. http://www.govindicators.org/ [accessed 10 March 2012].
27 Kaufmann D, Kraay A, Mastruzzi M. The Worldwide Governance Indicators: Methodology and Analytical Issues. World Bank Policy Research Working Paper No. 5430. Washington, DC, USA: The World Bank; 2010. p.31.
28 United Nations Children's Fund. State of the world's children 2012: children in an urban world. New York: UNICEF; 2012. p.152.

29 Houweling TA, Caspar AE, Looman WN et al. Determinants of under-5 mortality among the poor and the rich: a cross-national analysis of 43 developing countries. Int J Epidemiol 2005;34:1257–65.

30 Bakker FA, Gai Y, Gottret P. Government health expenditures and health outcomes. Health Econ 2007;16:257–73.

31 Forag M, Nandakumar AK, Wolack S et al. Health expenditures, health outcomes and the role of good governance. Int J Health Care Finance Econ 2013;13:33–52.

32 Muldoon KA, Galway LP, Nakajima M et al. Health system determinants of infant, child and maternal mortality: a cross-sectional study of UN member countries. Global Health 2011;7:42.

33 Zakir M, Wunnova PV. Factors affecting infant mortality rates: evidence from cross-sectional data. Appl Econ Lett 1999;6:271–3.

34 Chen B, Kan H. Air pollution and population health: a global challenge. Environ Health Prev Med 2008;13:94–101.

35 Millman A, Tang D, Perera FP. Air pollution threatens the health of children in China. Pediatrics 2008;122:620–8.

36 Ha EH, Lee JT, Kim H et al. Infant susceptibility of mortality to air pollution in Seoul, South Korea. Pediatrics 2003;111:284–90.

37 Bokhari FA, Gai Y, Gottret P. Government health expenditures and health outcomes. Health Econ 2007;16:257–73.

38 Feenstra RC, Inklaar R, Timmer MP. The Next Generation of the Penn World Table. http://www.ggdc.net/pwt [accessed 7 July 2013].

39 Kaiser H. The varimax criterion for analytic rotation in factor analysis. Psychometrika 1958;23:187–200.

40 Van de Poel E, O'Donnell O, Van Doorslaer E. Are urban children really healthier? Evidence from 47 developing countries. Soc Sci Med 2007;65:1986–2003.

41 Christian P. Impact of the economic crisis and increase in food prices on child mortality: exploring nutritional pathways. J Nutr 2010;140:1775–815.

42 Palma-Solís M, Gil-González D, Álvarez-Dardet C et al. Political and social context of not attaining the Millennium Development Goal to reduce poverty. Bull World Health Organ 2008;86:772–9.

43 Aklal FA, El-Saharty S. Public-health challenges in the Middle East and North Africa. Lancet 2006;367:961–4.

44 Ackley TK, Liang BA. Combating healthcare corruption and fraud with improved global health governance. BMC Int Health Hum Rights 2012;12:23.

45 Kirigia JM, Diarré-Nama AJ. Can countries of the WHO African Region wean themselves off donor funding for health? Bull World Health Organ 2008;86:889–92.

46 Morgenstern H. Uses of ecologic analysis in epidemiologic research. Am J Public Health 1982;72:1336–44.

47 Montgomery MR. Urban poverty and health in developing countries. Popul Bull 2009;64:2–16.

48 Woods R. Urban-rural mortality differentials: an unresolved debate. Popul Dev Rev 2003;29:29–46.

49 Ministry of the Interior, ROC (Taiwan). Statistical Yearbook of Interior. http://sowf.moi.gov.tw/stat/year/elist.htm [accessed 29 June 2013].

50 The World Bank. World Development Indicators (WDI). http://data.worldbank.org/indicator [accessed 23 December 2012].

51 Department of Health, ROC (Taiwan). Health Statistics [in Chinese]. http://www.mohw.gov.tw/cht/DOS/Statistic.aspx?f_list_no=312&fod_list_no=1717 [accessed 13 January 2013].

52 Environmental Protection Administration, ROC (Taiwan). Taiwan Air Quality Monitoring Network. http://taqm.epa.gov.tw/taqm/en/default.aspx [accessed 1 May 2012].