CORVINUS UNIVERSITY OF BUDAPEST

DO WATER ACCESS INEQUALITIES MATTER FOR CHILD MORTALITY?

A perspective from low-and middle-income countries

by

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Declaration:

I hereby declare that I am the sole author of the thesis entitled 'Do water access inequalities matter for child mortality? A perspective from low- and middle-income countries' I duly marked out all quotations. The used literature and sources are stated in the attached list of references.

In Budapest, August 2023 *Signature of the student*

Urangoo Bulgamaa

Dedicated to my mother

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Thesis in brief

Although the role of water is well known in child health, whether and how the distribution of water access affects child mortality and its economic transmission channels remain unclear. In particular, child mortality caused by diarrhea received insufficient attention, although diarrhea is the second leading cause of age under 5 mortality worldwide. The dissertation project addresses this gap by clarifying the theoretical /conceptual background of both child mortality and water access inequality, and by generating robust empirical evidence on whether water access inequality is a significant determinant of child diarrhea mortality in the context of low-and-middle-income countries by applying a mixed methods approach. To this end, the study provides a theoretical background of the dissertation (objective 1) by setting a story for health and economic development through a political economy lens (i), clarifying the determinants of child mortality from a health economics perspective (ii), clarifying the concept of socioeconomic inequalities in water access from a welfare economics perspective (iii), highlighting a plausible economic transmission channel (iv), and selecting concentration index approach as a preferred method to quantify water access inequality (v). Building on this background, we constructed a water access inequality index in order to reveal its global trend and patterns (objective 2). Consequently, we assessed the likely effects of water access inequality on child mortality outcomes by utilizing a panel approach (objective 3). Finally, a further empirical chapter revealed how water access inequality affected the 'success' and 'failure' of the efforts reducing child diarrhea mortality in the selected cases of Liberia and Zimbabwe through a comparative case study approach (objective 4). In doing so, we combined real-world open-access datasets from various international sources. The key findings of the dissertation suggest that water access inequality matters for child mortality caused by diarrhea in the context of low-and-middle-income countries (i) and water access inequality may hinder progress towards reducing child diarrhea mortality (ii). We attempt to contribute a better understanding of preventable child mortality, in which the role of distribution of water access is brought to the debate of global child mortality decline with robust evidence.

Keywords: *water access inequality, socioeconomic inequality, child mortality, diarrhea, economics perspective*

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List of Abbreviations

WII – water access inequality index

SII – sanitation access inequality index

LMICs - low- and middle-income countries

WASH – water, sanitation, and hygiene

U5MRD – Under 5 mortality caused by diarrhea

IMD – Infant mortality caused by diarrhea

IHME – Institute for health Metrics and Evaluation

GDP – Gross Domestic product

ORS – Oral rehydration solution

UNDP – United Nations Development Program

WHO – World Health Organization

UNICEF – United Nations International Children's Emergency Fund

UN – United Nations

JMP – Joint Monitoring Program

WDI – World Development Indicators

CI – Concentration index

SDG – Sustainable Development Goals

MDG – Millennium Development Goals

OLS – Ordinary least squares

FE – Fixed effects

RE – Random effects

ODA – Official development assistance

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All views and errors are my own.

Chapter 1

Introduction

1.1 Theoretical background and Justification of the topic

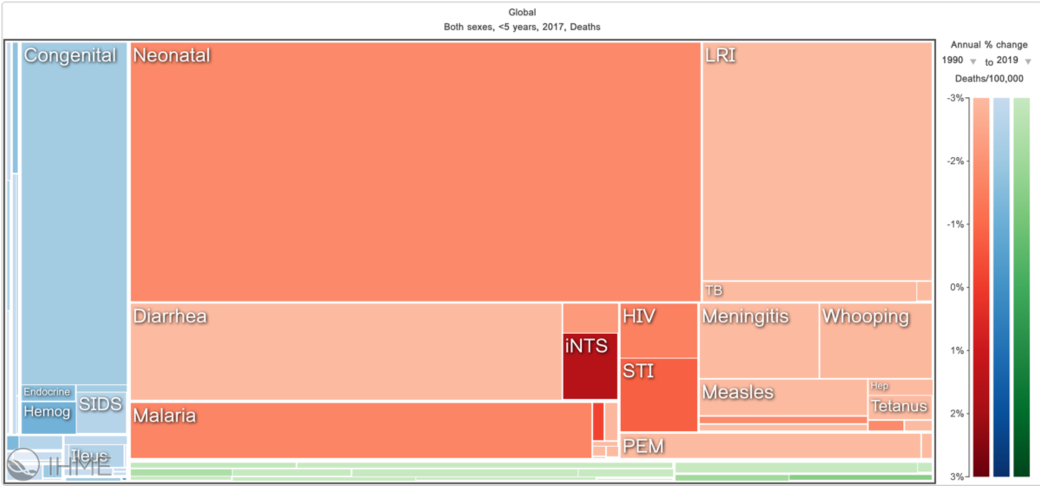
The primary focus of the dissertation project is to explore the intersection of water and health through an economics perspective. On one hand, water plays a vital role in human health and survival from the public health/epidemiological standpoint. On the other hand, it is a crucial resource for supporting flora and fauna from an environmental viewpoint. However, the significance of water has been neglected in the realm of economics research, resulting in its relative absence in the realm of policies as well. How can we continue to ignore such a critical resource that underpins life and the world? Motivated by this question, my interest was sparked to delve deeper into the role of water. It became evident, particularly during my participation in World Water Week back in 2019, that water stands at the heart of everything, interconnecting environment, ecology, biology, engineering, technology, health, development studies, anthropology, society, business, economics, politics, geopolitics, and international relations. Nonetheless, while traditionally environmental science and more recently interdisciplinary studies have taken on a more active role in this sphere. Consequently, approaches to the study of water are evolving from disciplinary to multidisciplinary, interdisciplinary, and transdisciplinary. This enrichment also reveals the complexity of the research problem - water.

Taking stock of the knowledge in the relevant literature, we recognize the role of health in economic development (Barro, 2013, 1996; Finlay, 2007; Grossman, 1972; Mushkin, 1962; World Bank, 1993) and human development (United Nations, 1990), on the one hand, and the role of water in health from a health economics perspective (Cutler et al., 2006; Cutler and Miller, 2005). On the other hand, we can approach water from a welfare economics perspective, addressing the distribution of water by asking '*Who gets safe water and who does not*?'. This question is particularly relevant in the context of low-and-middle-income countries, given that achieving a full coverage of access to safe water is still at the heart of global development agenda. Then the obvious follow-up question emerges connecting it to health: '*Whether and how this discrepancy affects health status of the people*?'. It then becomes as the central question of the dissertation project. By answering this question, we attempt to contribute this line of research from an economics perspective. In particular, the review of the literature reveals that whether and how the distribution of water access affects child mortality (i) and its economic transmission channel (ii) are unclear (Besnier et al., 2021; Fink et al., 2011; Hoddinott, 1997; Setty et al., 2020, 2019). Moreover, child mortality caused by diarrhea received nearly no attention in the literature, despite only one recent study published (Local Burden of Disease WaSH Collaborators, 2020).

Building on this theoretical background connecting *water access inequality* and *child mortality*, we look at the global health policy sphere to understand the dynamics of the child mortality, especially caused by the infections closely connected to water. The stylized facts yield the following insights. First, diarrhea is the second major killer of children age under 5 globally, after neonatal disorder (Figure 1). Second, diarrhea is the primary concern among the intestinal infections/water borne infections (Figure 2). Third, almost exclusively it is a development concern in low-middle-income-countries. The highest intensity of the disease burden lies in Sub-Saharan Africa, while the lowest burden appears in Europe and Central Asia (Figure 2). Fourth, Infants and children age under 5 are the most vulnerable age groups in mortality caused by diarrheal disease (Figure 3) apart from old age mortality. This demonstrates the relevance of our study.

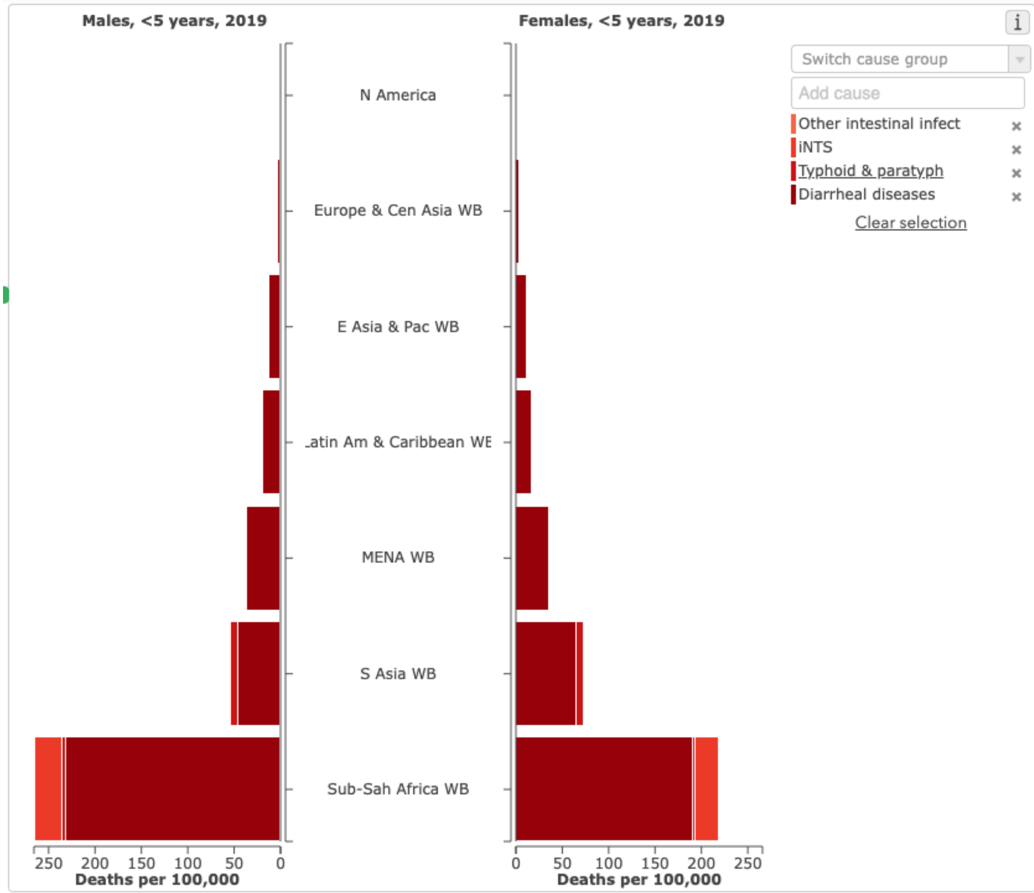
Chapter 2 provides a theoretical background of the analysis by clarifying the definition of socioeconomic inequality in water access, approaches to socioeconomic inequality, and economic transmission channel alongside the detailed discussion on the determinants of child mortality.

Figure 1. Diarrhea infection remains as the second major killer among



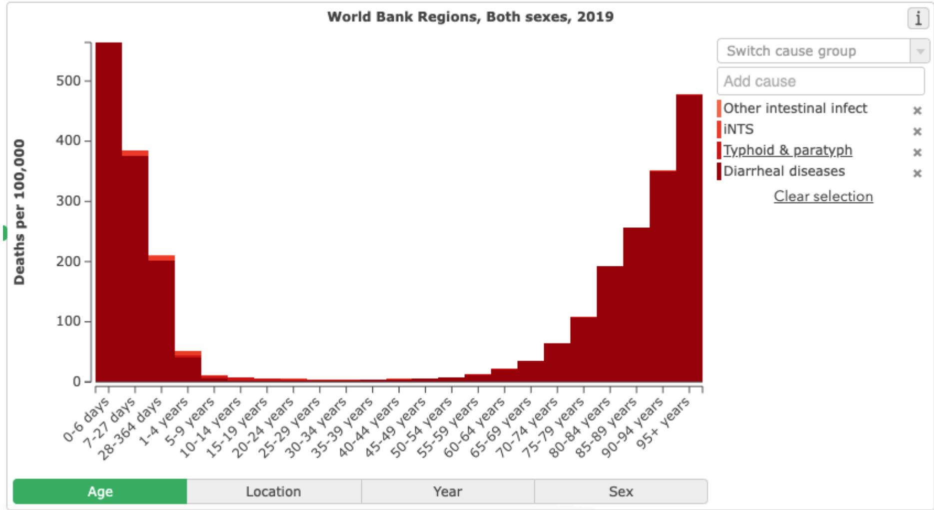
Source: IHME. GBD Compare Data Visualization: http://vizhub.healthdata.org/gbd-compare. (Institute for Health Metrics and Evaluation (IHME), 2020)

Figure 2. Mortality by intestinal infections by World bank regions



Source: IHME. GBD Compare Data Visualization: http://vizhub.healthdata.org/gbd-compare. (Institute for Health Metrics and Evaluation (IHME), 2020)

Figure 3.Mortality by the causes (intestinal infections) and age groups as of 2019



Source: IHME. GBD Compare Data Visualization: http://vizhub.healthdata.org/gbd-compare. (Institute for Health Metrics and Evaluation (IHME), 2020)

1.2 Scope of the study

The dissertation project aims to address the gap identified in the literature by clarifying the theoretical/ conceptual background of both child mortality and water access inequality (i) and by generating robust empirical evidence on whether water access inequality is a significant determinant of child diarrhea mortality in the context of low-and-middle-income countries by applying a mixed methods approach (ii).

To achieve this goal, we follow 4 mutually exclusive yet sequential set of objectives. First, we aim to provide a theoretical/conceptual background of the project by setting a story for health and economic development through a political economy lens (i), clarifying the determinants of child mortality from a health economics perspective (ii), clarifying the concept of socioeconomic inequalities in water access from a welfare economics perspective (iii), highlighted a plausible economic transmission channel (iv), and selecting a preferred method to quantify water access inequality based on the review of relevant empirical literature (v).

Second, building on this background, we construct water access inequality index in order to reveal its global trend and patterns by assessing 61 countries (objective 2) between 2000 and 2017 (N=61 and t=18).

Third, we assess the likely effects of water access inequality on the two child mortality outcomes by utilizing an extended panel approach with Driscoll-Kraay standard error and the panel data constructed for 47 countries covering the period between 2000 and 2017 (N=47 and t=18). In doing so, we combine the datasets from own estimates of Chapter 4 and other international sources to construct a multi-country, multi-year panel.

Fourth, the last empirical analysis aims to assess how water access inequality affects 'success' and 'failure' of the efforts in reducing child diarrhea mortality in the cases to be selected by applying a comparative case study approach.

Hypotheses

Theoretical literature yields hypotheses-1, which is tested in Chapters 5, while hypothesis-2 is tested in Chapter 6.

H-1: *Water access inequality* is significantly positively associated with *child diarrhea mortality*

H-2: *Changes in water access inequality (WII)* are significantly associated with *changes in child diarrhea mortality (CDM)*

Sub-hypotheses:

H-2.1: Decrease WII – Success CDM

H-2.2: Increase WII – Failure CDM

H-2.3: Absence of progress WII - Success CDM, if
the absence of change in WII is due to the presence of a high initial coverage of water

H-2.4: Absence of progress WII - Failure CDM, if
the absence of progress in WII is due to the absence of improvement towards full coverage of water

1.3 Data, Sources and Variables

The research project exploits publicly available international datasets from the Institute for Health Metrics and Evaluation (IHME), World Development Indicators, WHO/UNICEF – Joint Monitoring Program, UNDP – Human Development Index, and WHO. In doing so, a panel on the key explanatory variable (water access inequality) and a control variable (sanitation access inequality) were estimated by the author building on the WHO/UNICEF – JMP wealth-quintiles datasets for all countries in the sample. In doing so, we utilized data on basic category of water services (as well as sanitation services) as it is the second-best category, where wealth quintile dataset is available. This dataset is built based on the estimates of DHS & MICS household survey (WHO-UNICEF, 2018). Water access expressed by wealth quintiles are produced by applying Principal Component Analysis (PCA), following the method suggested by Filmer & Pritchett (2001).

The most influential academic journals in health economics include Journal of Health Economics, Health Economics, Health Services Research, Pharmacoeconomics, and Journal of Human Resources, while Top 10 most cited scientists globally were David M. Cutler, Jonathan Gruber, Paul Newhouse, Mark V. Pauly, W. Kip Viscusi, Janet M. Currie, Michael Grossman, Frank A. Sloan, Adam Wagstaff, and Eddy van Doorslaer, and the highest ranked institutions were Harvard University, World Bank, MIT, University of California at Berkeley, Chicago University, Pennsylvania University, Michigan University, and York University (Jakovljevic and Ogura, 2016, p. 2).

Table 1. Variables and Data sources

No	Indicator	Source	Scale
1	U5MRD	IHME	log scale, Per 1000 live births
2	U5MRD, female	IHME	
3	U5MRD, male	IHME	
4	IMD	IHME	
5	IMD, female	IHME	
6	IMD, male	IHME	
7	Water access inequality index (WII)	Own estimates using JMP data	log scale, ranges between -1 and +1
8	Sanitation access inequality index (SII)	Own estimates using JMP data	log scale, ranges between -1 and +1
9	GDP per capita	World Development Indicators	log scale, per capita PPP (current international $)

10	Gini index	World Development Indicators	log scale, 0-100, %
11	Female education	UNDP	log scale, Percentage of population
12	Physicians density	World Development Indicators	Per 1000 people
13	Health expenditure per capita	World Development Indicators	log scale, per capita PPP (current international $)
14	ORS coverage	IHME	log scale, Percentage
15	Cereal yield	World Development Indicators	log scale, kg per hectare
16	Urbanization	World Development Indicators	log scale, Percentage of population
17	Breastfeeding exclusive	IHME	Percentage

Note: The extended table with descriptions and the reasons for inclusion and exclusion of the variables are discussed in Chapter 3.

1.4 Methods

1.4.1 Concentration index as a preferred approach to socioeconomic inequality

Chapter 4 quantifies water access inequality index by applying Concentration index (CI) approach developed by the prominent health economists of our time (Wagstaff et al., 1991). It is rooted from a welfare economics foundation (Bleichrodt and van Doorslaer, 2006). As an alternative approach to socioeconomic inequality, CI is a competing approach to egalitarian approaches such as human opportunity index (HOI), which was built upon the concept of equality of opportunity (Paes de Barros et al., 2009; Roemer, 1998) and the concept of Equality of Capability (Sen, 1993, 1992). The key advantage of the CI approach is twofold. First reason is its efficiency and accuracy compared to HOI (Kanbur and Wagstaff, 2014) and other approaches such as The range, Lorenz curve and Gini index, Pseudo Lorenz curves and the index of dissimilarity (Wagstaff et al., 1991). Second, its pragmatic ability to be integrated into existing knowledge and datasets collected through decades of international collaboration compared to both. For example, CI is already integrated to measuring global health efforts such as Health Equity Assessment Toolkit (HEAT) of WHO. This idea is also highlighted by the inequality researchers (Cetrulo et al., 2020) suggesting it can be integrated to measuring water access inequalities under the umbrella of Sustainable Development Goal 6, despite its limitation for being unable to capture multidimensional aspects of inequality.

1.4.2 Panel approach

For Chapter 5, the panel fixed effects regression models are constructed to test the hypothesis – 1. In each model, each outcome variable is specified as a linear function of household water access inequality (Greene, 2003). For the period of 2000 and 2017, the model examines the child mortality effects of water access inequality. We interpolated and standardized by transforming into logarithmic values. We conducted 7 diagnostic tests to select the appropriate model and their extensions.

1.4.3 Comparative case study approach

Chapter 6 tests the hypothesis – 2 by looking at two country cases by applying comparative case study approach, following a political economy book (Benczes, 2023), in which I contributed Chapter 12 (Bulgamaa, 2023). This study compared two distinct cases through a paired comparison process to assess whether changes in water access inequality is associated with the 'success' and 'failure' in the efforts reducing child diarrhea mortality.

1.4.4 Software

The analysis was carried out in STATA 17.0 software. Some visualizations were generated in Tableau, the web-tools of World Bank, IHME, and MS Excel.

1.5 Findings

The key findings of the dissertation as follow:

- Water access inequalities matter for child mortality **(H-1).**
- Decrease in water access inequalities are significantly positively associated with success in child mortality reduction **(H-2.1).**
- Increase in water access inequalities are significantly positively associated with failure in child mortality reduction **(H-2.2).**
- Absence of progress in water access inequalities (WII) is significantly positively associated with *success* in child diarrhea mortality (CDM), if the absence of change in WII is due to the presence of a high initial coverage of water **(H-2.3).**

Conversely,

- When investigating two outliers, we fail to reject the null hypothesis of the H-2.4: Absence of progress in water access inequalities (WII) is associated with failure in child diarrhea mortality (CDM), if the absence of progress in WII is due to the absence of improvement towards full coverage of water **(H-2.4).**
- This suggests that water inequality effect can be camouflaged when testing on the total mortality data. Because we found evidence indicating (WII) inequality increased due to increased coverage for rich and decreased coverage for poor. In this case, the rich gains health, while the poor loses health, given that water and health are directly associated. In this case, health gain of the rich may offset health loss of the poor, which in turn appear as a net health gain for the general population. It, therefore, does not necessarily contradict the hypothesis on the relationship between water inequality - child mortality.
- It, therefore, suggests that inequality-inequality analysis (inequality in water access – inequality in child mortality).
- All in all, our findings broadly suggest that water access inequalities matter for child diarrhea mortality (i), and water access inequalities may hinder progress in efforts reducing child diarrhea mortality (ii).

1.6 Payoffs

Chapter 2 contributes the existing literature by three ways. First, its attempt to conceptualize water access inequality and highlight an economic pathway is often neglected in the published empirical studies. Second, clarifying a health economics approach to child mortality studies is an added value, given that the study of child mortality is interdisciplinary in nature and it is not often clearly stated. A myriad of existing studies approached from various different perspectives such as epidemiology, public health, social science, development studies, welfare economics, historical and neoclassical economics, make it even more difficult. Third, the conceptualization of this chapter as a whole is unique itself, given that an intersection of water and health research approached from an economics perspective is rare, not to mention its attempt to integrate the notion of distributive justice into the water variable.

The main contribution of Chapter 4 is generating water access inequality index, which allows a further analysis to assess its likely effect on child mortality outcomes. In doing so a new approach to water inequality discourse is applied to build a multi-country panel by borrowing from health inequality research. This approach has important advantages, compared to alternative approaches, such as more effective, more accurate, highly pragmatic and easy to integrate with existing datasets accumulated as a result of decades long international cooperation.

Chapter 5 contributes the literature by bringing a new explanatory variable – water access inequality – into the debate on global child mortality in which we attempt to recognize the role of the distribution of water access for child survival in LMICs, on the one hand, and exploiting a new global dataset on child mortality on the other. It also addressed limitations of the previous studies by focusing on socioeconomic aspect rather than geographic aspect of water inequality (Local Burden of Disease WaSH Collaborators, 2020) and applying a panel design rather than (repeated) cross-sectional design (Cha et al., 2017; Hasan and Alam, 2020). In constructing the panel, we used several techniques to improve its efficiency by interpolating (Anand and Bärnighausen, 2004; Jamison et al., 2016); extending the panel by including country-time-fixed-effects (Greene, 2003) and Driscoll-and-Kraay standard errors (Hoechle, 2007); and performing robustness check with alternative datasets. In addition, we complement the study by approaching through in-depth comparative analysis in Chapter 6.

1.7 Structure of the thesis

Chapter 2 covers the review of the literature to explain the theoretical basis of the research project. It starts by highlighting the role of health in economic development, followed by the key determinants of child mortality and the relationship between water/water access inequality and health are visited in the subsequent sections. Chapter 3 explains research design and methodology by describing each analytical approach in-detail and by visiting ethical considerations. Moving forward, Chapter 4 presents the quantification of water access inequality index. Building on the index, it provides a trend and patterns of water access inequality in global comparison, and the international ranking of the countries in terms of their achievements in tackling water access inequality between 2000 and 2017. Consequently, the likely effects of water access inequality are tested on child mortality outcomes by a quantitative approach in Chapter 5. Conversely, Chapter 6 cross-examines the relationship between changes in water access inequality and changes in child mortality by applying a qualitative method in the cases of Liberia and Zimbabwe. In the end, the research project is concluded in Chapter 7 in which future research agenda and policy implications are also formulated.

Chapter 2

Literature Review: Theoretical Background

2.1 The role of health in economic development

Health is as a key factor in productivity, a significant contributor to economic growth (Barro, 2013, 1996; Finlay, 2007; Grossman, 1972; Mushkin, 1962; World Bank, 1993), and a major component of human development (United Nations, 1990). It, therefore, comes to development policy with a high degree of importance. Its relevance in economic development receives an increasing attention in the relevant literature over the years. Although the role of health received more attention in the literature of economic development by 1990s, health has been studied as a key research problem in health economics since the late 1950s and 1960s (Jakovljevic and Ogura, 2016; Mushkin, 1958), in which the focus was mainly the role of health care and health system functioning.

From a political economy perspective, global health improvement is seen as a development progress, largely benefitting from international cooperation. It has been greatly facilitated by the International Development Programs due to the subsequent development of international relations. For example, the World Health Organization (World Health Organization, 2003), which has been at the forefront of international health efforts since 1948; the Millennium Development Program in the early 1990s; and, most recently, the Sustainable Development Program, which could be mentioned. This yields a story that builds upon the subsequent development of ideologies in the post-world war era. Although health was not directly the main focus of development ideologies such as capitalism, structuralism, it eventually came into the context under the globalization and human development theories. However, one common theme, that emerges from the story of global development, is the aim - *tackling poverty* was the shared mission of all these paradigms. Yet, they differed in their ways to deal with poverty. The concept of poverty is multifaceted. There is income poverty (European Commission. Eurostat., 2010), health poverty (Clarke and Erreygers, 2020), and a multidimensional poverty which accommodates multiple indicators of wellbeing (i.e., multiple deprivations) including child mortality and access to water through aggregating them into a composite index (Alkire, 2007; Alkire and Foster, 2011). To discuss how these approaches differ in approaching poverty, we briefly visit them one by one alongside setting a story that presents how these ideologies fall and rise, how the challenges within the paradigms were been viewed, and how contemporary economic literature approaches development.

The post-World War II development paradigms originated with capitalism in the West and socialism in the East. These ideologies were dominant in the early 1960s-70s. The Western led economic development was underpinned by Rostow's modernization theory, which revolves around inclusive market economies. This theory advocated the idea that capitalism paves the way for favorable development outcomes (Rostow, 1960). On the contrary, East proposed structuralism as an alternative path to development, standing in contrast to the modernization theory. Structuralists explicitly claimed that the capitalism is the root cause of the social struggles and underdevelopment. Dependency theory addresses underdevelopment within and between nations in the context of neo-colonialism. It stands in opposition to capitalism asserting that the poor countries (periphery) cannot catch up the rich countries (core) as a result of modernization, instead the gap only increases. This is primarily due to an unequal exchange and the extraction of resources, forming the foundation of this disparity (Amin, 1976; Balogh, 1963; Myrdal, 1969; Prebisch, 1970). Furthermore, dependency theorists were divided as the liberal reformists and neo-Marxists. The former preferred the interventions as an approach to solve the problem, while the latter adopted the command-centered economy. Furthermore, Szentes revisited the world economics through equality lens. In his book, he asserted that the asymmetrical interdependencies between the countries caused underdevelopment and difference. As a consequence, it escalated a shame and threat for the human society as a whole that causes unequal conditions. Thereby, he further questioned economic globalization and highlighted the importance of national competitiveness (Szentes, 2003; 2011). Another theory, that lost its relevance is the World Systems Theory. It approached economic development from the position of a total world system, rather than the individual countries. Wallerstein claimed that the world system itself is a reason to generate inequality (Wallerstein, 1974). The idea behind this theory was the same as that of the dependency theory, however, it differed by the idea of semi-periphery countries where poverty declined. Wallerstein's argument about the root cause of underdevelopment was exploitation the previous authors. The idea is that both poor countries and poor people are exploited by the rich countries and the rich people.

In the 1980s and 1990s, the theory of globalization emerged as a dominant development paradigm, following the world systems theory due to the efforts integrating global economies. Contrary to the structural theories, it focuses on integrating people and economies through **a** technology-based communication (Reyes, 2001), therefore, the importance of individual state shifts to the flexibility of technology to connect people. It bears resemblance to the world systems theory in terms of scale and shares similarities with the dependency theory in its emphasis on integrating international economies. Under this paradigm, neoclassical economic theory promotes the idea of market liberalization and emerged as a dominant framework.

Following the 2008 Global Financial and Economic Crisis, the critiques escalated in which the major concerns were poverty and inequality. This leads to the question: *which system actually lifted people out of poverty?* Post-Keynesian scholars advocated capitalism bringing evidence on how capitalism has been lifting people out of poverty, although it is not without its problems. The problems perhaps stemming from how the countries participates in capitalism, perhaps its exclusion rather than its inclusion, and/or malpractice within it, which keep the countries from succeeding (Acemoglu and Robinson, 2012). However, the book 'Pharmaceutical Industry and Dependency in the Third World' (Gereffi, 1983) exposed a malpractice of the transnational corporation of pharmaceutical industry operating in Mexico. The story showed how the corporation benefitted from transfer pricing and exploited the locals. Moreover, there is an important line of literature, institutional economics is sought to fix the market failures by the means of the institutional constraints (North, 1991) alongside the help of democratic processes such as elections and institutional checks and balances, independent media that harness transparency and accountability to address a governance-failure.

The second question on a key development challenge of our time is about inequality: *who benefits from globalization and who does not?* Joseph Stiglitz addressed economic inequality from a perspective of new Keynesian economics by advocating the idea that divided society endangers our common future (Stiglitz, 2012). Although dissertation does not engage in the role of economic inequality in development, it does engage in the health consequences of the distribution of water access. The details are discussed in the separate section.

2.2 The determinants of child mortality outcomes

In this section, we aim to discuss the relevant theoretical literature and identify the key determinants of child mortality. There is no comprehensive theory[1] that explains the mortality decline, however, several theories tried to explain this from different perspectives. The debate is, therefore, revolving around the question: *what was the major factor that caused the mortality decline*. There are competing views. The four key factors, in this debate, are economic change, social, change, bio-medical technology change (Jamison et al., 2016), and the role of public health (Cutler et al., 2006). The theory of globalization resonates well with the explanations of global mortality declines and increases in life expectancy. Which include Economic Growth Theory, Public Health Theory, and Big Medicine Theory.

Economic Growth Theory explains global child mortality decline in several ways. As a consequence of economic growth on health, there are several views that explain the relationship. First, *economic growth* is the most important determinant in reduction of mortality and betterment of human health status (Filmer and Pritchett, 1999, 1997). However, there is also a contrary argument that population health has improved in many low-and-middle income countries regardless of their economic situations. Therefore, health studies on the role of health expenditure do not support such the claim of neoclassical economists.

The second view sheds light on the role of *nutrition*, as a key health improving factor brought by economic growth (Fogel, 1997). Fogel asserted that agricultural development enabled food availability, in turn, it improved a nutritious status of people. Better nutrition is translated into better immunity. Hence, in his finding, taller the people - stronger the immunity, therefore, taller people tend to out-live shorter people. In either of these studies, economic growth played a significant role in determining health outcomes, on the one hand, and appears to be a consequence of globalization, on the other. In general, there are unorthodox views that emphasize the role of public interventions and deemphasize the role of economic growth as a sole factor in public health betterment. This issue was underpinned by David Cutler, Angus Deaton, and Lleras-Muney, experts in health economics, development economics and public

[1] I am aware of a very popular framework, the concept of child survival (Mosley and Chen, 1984) . This concept builds upon epidemiological and social theories to integrate the determinants from these two areas of studies. However, there is very little space for economic determinants. Therefore, this framework is not suitable for the purpose of our study.

health (Cutler et al., 2006) in such a way that the health effect of economic growth, especially during the times of Big Medicine Era, may be camouflaged by the population increase, building on the evidence suggested by Acemoglu & Johnson (2006). They extend the idea that GDP per person drops, at least for temporarily, due to the population growth. Because mortality decline affects population growth by benefitting from health technology improvements. Since the GDP per capita as a key economic growth indicator in empirical studies, the actual effect of economic growth could be reduced in a per capita value.

Urbanization, as an important determinant of child health, came to health research following economic growth variable. The idea is that economic growth promoted urbanization (i.e., population growth) in the urban areas. There are two views relating to the health effects of urbanization. First, urbanization is bad for health due to the population density increase, which creates a situation in which infectious diseases easily transmit if a number of populations in city exceeded the optimal level (Van De Poel et al., 2012). Second, urbanization is good for health, as the living condition improves by benefitting from the process of urbanization through creating cities, expanding urban/public health infrastructures, access to healthcare and access to economic resources (Amouzou and Hill, 2004; Leon, 2008; Zhang et al., 2023).

Another important theory explains global mortality decline is **Public Health Theory** (Preston, 1996, 1980, 1975). This theory basically explains the public health interventions focused largely on preventing infectious diseases based on the epidemiological knowledge brought by the Germ Theory of Disease by 1960s. These interventions include purifying water, sterilizing milk, building infrastructures for clean water supply, sewage and sanitation systems. Public health theory explains the role of public interventions based on the epidemiological knowledge in improvements in population health by contrasting it to the role of economic growth (Cutler et al., 2006; Cutler and Miller, 2005). The idea behind here is that the role of public health interventions is emphasized, and the role of economic growth is deemphasized, holding an idea that, for example, mortality declined regardless of economic situation. Therefore, it is easy to assume that the Germ theory of disease was diffused throughout the world and integrated at the country level interventions. It then resulted in mortality decline. Global organizations such as World Health Organization and United Nations have played a major role in coordinating the efforts to control the disease burden and related mortality. In addition, World Bank positioned itself on the map by participating in the discussion on the relevant theory and policy. The bank dedicated a World Development Report: 1993 on health, accommodating a range of views and studies surrounding this topic (World Bank, 1993). In their work with the bank, Yusuf and Deaton emphasized the role of clean water in health in such a way that:

> This is well acclaimed understanding that If people are living longer and healthier lives, that is mainly because of better nutrition, cleaner water, a better urban environment, and rising education. (Yusuf and Deaton, 2009, p. 78)

The third theory is **Big Medicine Theory – the role of immunization**. Globalization enabled free flows of information and medical technology from the places where it is abundant to the parts where it is scarce. Therefore, people's health largely benefitted from the advancement in medical technology and its diffusion not only in developed world but also in developing world. For example, the role of immunization has been immense in controlling the communicable diseases. Although there is a mounting evidence on the role of vaccination, as a key intervention, in public health literature, while the studies in economics literature is scarce. Jamison and colleagues (2016) studied the recent child mortality decline from a perspective of neoclassical economics by applying the Solow model (Solow, 1957). In this study, vaccination is considered as a technical progress. They suggested an evidence on the significant role of technical progress in recent global child mortality declines in such a way that the differing levels of technical progress may explain the differing levels of mortality decline between countries by analyzing the cross-country panel data.

Female education appears as a key driver in social change, that played a key role in reducing child mortality globally. This view is generally accepted in the relevant economic (Cutler et al., 2006; Jalan and Ravallion, 2003; Jamison et al., 2016), social (Caldwell, 1994, 1986), and epidemiological literature (Mosley and Chen, 1984). There is mounting empirical evidence supporting the role of female education in child health outcomes including mortality and morbidity. Some of them are (Andriano and Monden, 2019; Basu and Stephenson, 2005; Bicego and Boerma, 1990).

Health care delivery is an important determinant in child health (Cutler et al., 2006). Economists study the resource variables of health care, such as health expenditure, while public health scholars focus more on access and utilization of health care, although they also study the effectiveness of health expenditure. There are two views about the health effects of health expenditure. First, higher health expenditure is significantly positively associated with the health (Kim and Lane, 2013; Kiross et al., 2020; Novignon and Lawanson, 2017; Nyamuranga and Shin, 2019). Second, health expenditure is not an effective factor (Filmer and Pritchett, 1999, 1997; Terrelonge, 2014), instead economic growth is much more effective (Filmer and Pritchett, 1999, 1997). Moreover, there are studies suggesting that human resources of health care sector is important in population health outcomes (Anand and Bärnighausen, 2012, 2007, 2004).

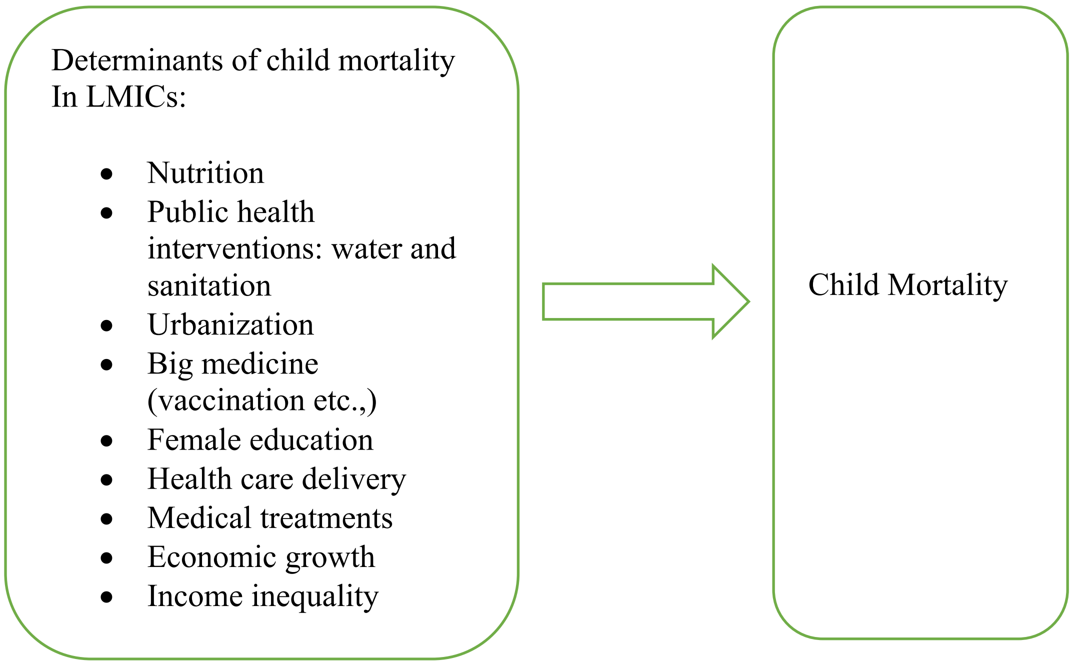
Medical treatments are obvious determinant of child mortality, specially, for diarrheal disease, which is not only preventable but also treatable. Biomedical development brought a cheap and effective treatment available for diarrheal disease, which is Oral Rehydration Treatment/ Oral Rehydration Solutions (Cutler et al., 2006; World Health Organization, 2022). Although an availability of treatment does not necessarily mean a usage of treatment when needed. A recent study underlined this point, which concluded that there is need to educate mothers about the usage of Oral Rehydration Solutions in countries where the disease burden is high (Binder, 2020).

Economic inequalities seem to play an important role in explaining health status, if the health effect of economic growth hypothesis holds. The most widely cited economic inequality[2] determinant in health is income inequality. Wilkinson & Picket assert that income inequality may determine ill-health based on over 300 studies investigating this relationship (Pickett and Wilkinson, 2015a; Wilkinson and Pickett, 2006). Although Deaton contradicts the role of income inequality in health, mostly because the fact that he advocates the relationship: ill-health causes income inequality, but not the opposite. At the same time, he accepts the role if income inequality for child mortality outcomes through poverty, given the idea that income inequality efficiently captures poverty in low-and-middle income countries (Deaton, 2003). There is a debate on whether poverty or inequality as a determinant of ill-health (Pickett and Wilkinson, 2015b; Rambotti, 2015). In the simplest definition of poverty and (income) inequality, the former is about the number of populations living under the line of poverty (in a neoclassical definition, but it is defined in a much more complex way in unorthodox definitions such as multidimensional poverty), while latter captures the differences of income between the social groups (although there can be a considerable difference in definition depending on the estimation method implemented). Wagstaff and Van Doorslaer found in their intensive review

[2] Economic inequalities are divided by the different themes such as income inequalities, consumption inequalities, and wealth inequalities.

that absolute income hypothesis more likely held, while there was only indirect evidence on deprivation hypothesis (Wagstaff and Van Doorslaer, 2000).

Figure 4. Determinants of child mortality in LMICs, a health economics perspective



Own construct. Based on the literature review.

2.3 Water and Health: State of the art of research

The role of water as a determinant of child health status is well known (Esrey et al., 1991; Gunther and Fink, 2010; Szreter, 1988; Watson, 2006a; Woods et al., 1988, 1989). This relationship is widely been studied in public health and epidemiological research, in which biological pathways are well highlighted. Yet, conceptualization of water access inequality is unclear (i), the role of socio-economic dimension of water access inequality as a child health determinant is unclear (ii), and the economic pathways are unknown (iii) (Hoddinott, 1997). On the other hand, child mortality outcomes received a very little attention compared to child morbidity outcomes in examining the effect of water (iv) (Fink et al., 2011), in particular, cause-specific-child mortality outcomes (v).

Hence, the dissertation investigates the role of distribution of water access (not access to water) in child mortality from a multidisciplinary perspective. In doing so, literature review in this section starts by defining the concept of water access inequality from a welfare economics perspective (i), then clarifies the variation of inequality we adapted in our research in comparison to the alternative inequality concepts (ii), sheds light on a plausible economic pathway through which water access inequality may affect child mortality (iii). We then discuss the related empirical studies in detail, guided by the above identified research gap (iv) and present how water access inequalities have been measured to date (v).

2.3.1 Socioeconomic inequality in water access

Access to water can be defined from multiple perspectives such as water as a human-right (law), a public health intervention (public health), a provision of public service (public economics), a commodity (neoclassical economics), a common-pool resource (new institutional economics), a basic need (welfarist approach), a basic opportunity (normative approach), a functioning (capability approach). In our research, we take a welfare economics perspective to define the distribution of water access by considering water access as a basic need.

In line with rank-dependent concentration index approach, building on Wagstaff, Paci, and van Doorslaer (1991), we define water access inequality as the extent to which inequalities in water access are related to indicators of socioeconomic status such as income[3]. As suggested by Bleichrodt and Van Doorslaer (2006) a welfare economics foundation builds the ground for the definition of health inequality in which several measures were used including concentration index. The authors demonstrated it by comparing several health inequalities measures, particularly highlighting their similarities. Earlier Bommier and Stecklov (2002) attempted to provide a theoretical foundation for health inequality from a normative perspective by building on A Theory of Justice (Rawls, 1971). In doing so, they initially approached from a Social Welfare Theory by following Atkinson and Bourguignon (1982), yet arrived at a negative conclusion. It then let them justify the choice of Rawls' Theory of Justice to provide a theoretical ground for the concentration index method of inequality. However, this conclusion

[3] For an empirical purpose, we incorporated wealth index, instead of income, to capture socioeconomic effect building on the work of Filmer and Pritchett (2001). The details are discussed in Chapter 3.

was debunked by Bleichrodt and Van Doorslaer (2006) as they demonstrated how the assumption of Bommier and Stecklov (equating health equity and health inequality[4]) was the culprit in bringing them into such the conclusion by proving the equation of each inequality measure through a set of theoretical assumptions of the Social Welfare Function, on one hand, and successfully built a theoretical foundation for the application of concentration index in socioeconomic inequality research, on the other.

2.3.2 Approaches to socioeconomic inequality

Since Wagstaff, Paci, and van Doorslaer (1991) suggested **Concentration Index** approach to measure socioeconomic inequalities in health, by mostly learning from income inequality research in mainstream economics, the research on socioeconomic inequality has increased immensely. This method resembles a welfarist approach in economics, particularly in income inequality. Parallelly, normative approaches to socioeconomic inequalities have also been contributing to the debate (Roemer, 1998; Sen, 1993, 1992). Roemer's concept of **Equality of Opportunity** quickly came to health inequality research, particularly the application of this measure in Latin American research has increased recently by the empirical application of Human Opportunity Index (Paes de Barros et al., 2009). At the same time, Sen's concept of **Equality of Capability** underpins the same problem from a different perspective. However, the approaches of Wagstaff and Roemer have been applied more broadly in empirical research than Sen's approach. The key reason perhaps lies at the extent to which a selected approach is operationalizable and feasible.

Increasing empirical studies applying the (in)Equality of causes concerns and receives criticism for three reasons: ethical disagreements on basic concepts (Kanbur and Wagstaff, 2014) (i) an underestimation of the amount of inequality that is unfair due to the inequality measurement strategy – the index of dissimilarity - adapted (Kanbur and Wagstaff, 2014) (ii) and a tendency of conceptual overlapping between equality of opportunity and equality of outcome (Chiappero-Martinetti, 2009) (iii). Both of literature highlighted policy consequences when relying on equality of opportunity theory. Moreover, Kanbur & Wagstaff's criticism seems to reflect the limitation relating to the accuracy highlighted in their working paper: Equality of Opportunity – Theory and Evidence (Ferreira and Peragine, 2015). These criticisms were

[4] The concept of health equity is different than the concept of health inequality.

significant factors in selecting the quantification strategy to water access inequality in the dissertation. We, therefore, relied on concentration index approach, in turn, it underpins conceptualization of the distribution of water access. We discuss the methodological details in Chapter 3.

2.3.3 Economic pathway

It seems water access inequality affects child health through poverty. Intuition is water access tends to be associated with living condition and location of home. Richer people are guaranteed to have home which has access to adequate drinking water and safe sanitation facilities. They tend to be granted access to these facilities at schools and hospitals as well. Whereas poor people tend to lack such access to these facilities, especially in developing world because the universal access to clean water and safe sanitation facilities are realized in most parts of developed world. In similar vein, Deaton highlighted poverty channel through which health effect of income inequality is quite well captured especially in the context of low-and-middle-income countries (Deaton, 2003).

2.3.4 What do previous studies say about water and water access inequality in child health?

We attempted to review the following relationship: *water access inequality* AND *child health* to see how much research has been conducted to fill the gap identified more than twenty years ago. We found only two study published falling under this specified category. Hasan and Alam, (2020) looked at the aspect of socio-economic inequality in water access, while Local Burden of Disease WaSH Collaborators (2020) looked at the geographic inequality in water access. At the same time, some very recent published papers highlighted a need for research investigating the relationship between water inequality and health (Besnier et al., 2021; Setty et al., 2020, 2019). These findings confirm a strong need for research on the likely effect of water inequality on health.

Hasan and Alan (2020) studied child morbidity (diarrhea), instead of child mortality outcomes. This study was cross-sectional in design, not a panel design. They studied subnational inequality in water access using the Proportional Variability (PV) and Pairwise comparison methods to quantify water access inequality based on the latest available DHS data of 2017.

Although the authors estimated water access inequality, they did not test its effect on child diarrhea, instead, tested the effect of water coverage on child diarrhea by applying a simple regression model. The findings of this study suggest a negative effect of drinking water coverage on child diarrhea. Although this study attempted to fill a research need by comparing multiple countries based on the important dataset, its major drawback comes with its cross-sectional design and a simple regression analysis relied on.

(Local Burden of Disease WaSH Collaborators, 2020) estimated averted diarrheal disease mortality attributable to geographic inequalities in water and sanitation access but did not look at the socio-economic aspect of inequality in access. The collaboration of over 600 researchers used a comparative risk assessment framework to construct counterfactuals and assess child mortality averted due to increased access. They used data of geographic inequalities in water and sanitation attributable to diarrhea mortality from Reiner and colleagues in addition to Gini based estimates. Highly empirical this study was heavily relied on statistical estimates to provide evidence on the global progress towards water and sanitation for all. Their finding suggests that changes in safe water access, on average, averted child mortality, but the number of averted mortalities was lower in some locations.

Since there is not enough studies focusing on water inequality and child health, I review the studies focusing on the effects of water[5]. On the left-hand side, our outcome variable is child mortality. I, therefore, reviewed the relevant studies to know what previous studies have found, and how they were conducted. All studies under this category were concentrated on the *all-cause-child-mortality* outcomes. These studies were published in the journals of different science disciplines. Three studies were in public health (Akachi et al., 2018; Fink et al., 2011; Gunther and Fink, 2010), two studies in economics (Lu et al., 2020; Ummalla et al., 2022), one in development economics (Cutler and Miller, 2005), and one study in environmental science (Cheng et al., 2012a) despite historical literature in public health (Szreter, 1988; Woods et al., 1989, 1988), and public economics (Watson, 2006b).

[5] We did not survey the mounting studies on the relationship between water and child health, which are mainly in the field of epidemiology and public health. Building on the significant and the most commonly cited review papers, we departed our studies from the point that water has a significant effect on child health. We, therefore, aim to test whether there is a distributional role of such an important resource on health, and highlight the economic pathway, if that effect exists.

Findings of the majority of studies support the hypothesized relationship, suggesting that water significantly affect child mortality (Cheng et al., 2012b; Cutler and Miller, 2005; Fink et al., 2011; Gunther and Fink, 2010; Lu et al., 2020; Sommer et al., 2015; Szreter, 1988; Ummalla et al., 2022; Watson, 2006a; Woods et al., 1989, 1988).

On the contrary, Akachi et al., (2018) found no significant impact of water access on the child mortality. An innovation in the work of Akachi and colleagues were controlling immunization among other interventions when testing the effect of water, among others, on child mortality age under 5. Due to data scarcity, controlling immunization was previously not possible as seen and stated in the previous studies (Fink et al., 2011; Gunther and Fink, 2010). This finding throws doubt on the claims that adequate water matters for child mortality. I, therefore, closely looked into Akachi et al (2018).

I find three reasons to suspect that the findings of Akachi et al may camouflage the effect of water on the mortality caused by *water-borne-diseases such as diarrhea.* First, they investigated *all-cause-child mortality*. This is aggregate mortality data, which includes not only diarrhea induced mortality, but also mortality induced by all other non-water-borne diseases. Second, *none* of the listed vaccinations controlled in their study addresses diarrheal infection. Third, they found that full vaccination coverage together with breastfeeding was associated with child mortality, whereas 15 out of 17 interventions found to be insignificant. If vaccinations against multiple causes of mortality was significant, on one hand, and considering the components of all-cause mortality data, in which majority of the diseases, which are sensitive to these vaccinations, are much bigger than diarrheal diseases, on the other hand. Diarrhea caused death is estimated as 9 % of all mortality among children age under 5 as of 2019 (UNICEF, 2022). These reasons seem to support my suspect.

2.3.5 Measuring water access inequality

Since *water inequality - health* research is rare, we surveyed studies that somehow quantified water access inequality without necessarily connecting it to health outcomes. This part aims to map how water access inequality has been approached and what econometric methods were utilized in research.

Water access inequalities is conceptually vague. Inequalities in access to water start getting scholarly attention relatively later than that of health research as the issue under question was only officially integrated in the UN framework in 2010[6]. It is therefore relatively new research. Adapting the UN classification of income inequality (UNDP, 2003), water access inequalities are also investigated as 'within-countries', 'between-countries' and 'global inequality' among peoples. Empirical papers estimated three categories of water access inequality: geographic inequalities (1), economic inequalities (2) and individual and group related inequalities (3).

Water access inequalities have been studied from geographic, economic and social perspectives depending on the stratifier used. For example, if the study focuses on the regional differences, it is commonly referred as a geographic inequality in water access. If the racial and ethnic backgrounds are analysed as a stratifier, it is defined as individual and group related inequalities. However, the empirical studies that examined these differences were not paid much attention on conceptualizing water access inequalities. As ODA report informed that spatial inequalities, wealth or income-based inequalities of water access have been dominant because the relevant data is the strongest in these particular directions (ODA 2017).

The studies under review estimated inequalities in access to water and sanitation at the sub-national, national, regional and global levels[7]. Global and regional scale studies mostly looked at inequalities 'within countries' and 'between countries' based on the country data and sub-national data in which they were disaggregated by rural and urban areas (Bayu et al., 2020; Cha et al., 2017; Fuller et al., 2016; Queiroz et al., 2020; Roche et al., 2017). Six studies investigated single countries both in the developed and developing regions. It is notable to reveal that the inequalities in access to water and sanitation are not only existing in the countries that are economically weak (Afifah et al., 2018; Azage et al., 2020; Cetrulo et al., 2020; Chaudhuri et al., 2020; Chaudhuri and Roy, 2017) but also in an advanced economy such as the United States of America (Gasteyer et al., 2016).

[6] The United Nations General Assembly declared that equitable access to water and sanitation is a human right, therefore ensuring such access to everyone is playing an important role in realization of all human rights (UNITED NATIONS GENERAL ASSEMBLY, 2010).

[7] Those scales of analysis - the sub-national, national, regional and global levels – have no special correlation on selection of the measures. On the contrary, which have a strong relevance to the level of disaggregation and coverage of the data.

Despite recognition of JMP method as a dominant approach which allows for global WASH inequality comparison through JMP wealth quintile method[8] (Bayu et al., 2020; Overseas Development Institute, 2017) the reviewed papers most frequently used Gini coefficient in their estimations or alongside with other estimation methods to allow comparison (see: Table 2) (Bayu et al., 2020; Cetrulo et al., 2020; Chaudhuri et al., 2020; Chaudhuri and Roy, 2017). A few papers applied simple disaggregation method mostly to allow comparison (Cetrulo et al., 2020; Cha et al., 2017; Chaudhuri and Roy, 2017). Cetrulo et.al., (2020) then endorsed the concentration index approach as the most appropriate method among other methods, in terms of feasibility and effectiveness, after comparing it with the various methods such as Simple disaggregation, Dissimilarity index, Generalised Entropy measure and Atkinson's index.

Alternatively, Queiroz and colleagues (Queiroz et al., 2020) suggested an alternative approach that looks at the intersecting forms of inequality accounting for various determinants that define a condition in which a person is disadvantageous. However, application of this approach is limited due to lacking data as acknowledged in their paper.

Most of these studies were descriptive in nature. Which means they quantified a various type of inequalities using different data and methods without building any sort of association or causality (Afifah et al., 2018; Azage et al., 2020; Cetrulo et al., 2020; Chaudhuri and Roy, 2017; Fuller et al., 2016; Queiroz et al., 2020; Roche et al., 2017; Wang et al., 2019).

Only five papers among others built an association between water access inequality and the causes of lacking access to water. They illustrated that social and economic (Chaudhuri et al., 2020; Gasteyer et al., 2016; Jimenez-Redal et al., 2018), governance (Bayu et al., 2020) and policy variables (Cha et al., 2017) are associated with lacking access to water. In these studies, the authors relied on Logistic Regression, Simple Linear Regression, and Multivariate Regression approaches.

Most studies under review relied on open datasets from WHO/UNICEF, USAID and OECD (Azage et al., 2020; Bayu et al., 2020; Cha et al., 2017; Chaudhuri and Roy, 2017; Fuller et al., 2016; Roche et al., 2017), and few used data from the national statistical offices and

[8] The JMP Wealth Quintile Analysis: more details can be found
The latest WHO/UNICEF Joint Monitoring Programme 'JMP Methodology Note 2017'
washdata.org/report/jmp-methodology-2017-update

international projects (Afifah et al., 2018; Cetrulo et al., 2020; Chaudhuri et al., 2020; Gasteyer et al., 2016). Only one study used primary data that were collected for the research (Jimenez-Redal et al., 2018). There is no single dominant measure found, instead there is a variety of measures employed in the research depending on the aim and the scope of the study. The process of producing literature review can be further read in the book chapter (See: Bulgamaa, 2021).

These papers offer valuable insights on the part that is related to socio-economic inequality in water access, how it has been measured, what data was used, whether these datasets are publicly accessible. On the other hand, it again indirectly suggests the health effects of water inequality should be studied.

The dissertation is inspired by the work of Bayu and colleagues (2020), who quantified inequalities in access to water and sanitation based on the cross-sectional data using JMP 2017 dataset and looked at the causes of water access inequality. They used Gini coefficient approach to quantify inequalities and applied a principal component analysis to assess water governance indicators in relation to the estimated inequalities. Their findings suggest that poor households are often excluded from basic services, and the economic aspect of water governance strongly affects such inequalities.

Although this study is informative in its way, I noticed a room for improvements. First, they used 2017 data (cross-sectional) to quantify and compare the countries in terms of Gini coefficient of water access in country X. Cross-sectional data is useful to explore a pattern, but unhelpful to explore trend. To allow cross-country over time analysis, we need to build water access inequality estimate for country *n* and time *t*. Moreover, Lorenz curve and Gini index fail to account for socioeconomic dimensions of a related indicator, although it accounts for experiences of all people rather than the differences of lowest and highest ranked groups (Wagstaff et al., 1991a). To address this problem, the Concentration Index approach is ought to be used. Furthermore, this approach is suggested as the most feasible and efficient approach in quantifying water access inequality by Cetrulo and colleagues (2020), if not integrating other aspects of water access inequality such as race, gender, etc. They showed the application of the Concentration Curve and Concentration Index in Brazilian census data alongside comparing it to other approaches such as Simple Disaggregation, Dissimilarity index, Generalized Entropy measure and Atkinson´s index. These measures were adapted from economic inequality research to health inequality research earlier, and most recently to water inequality research.

In general, summary measures of inequalities of X (that can be anything, in our case it is water access) that were reviewed in this chapter are classified by three groups: simple measures (1), regression-based measures (2) and complex measures (3) according to Lkhagvasuren (Lkhagvasuren, 2018). The concentration index method is one of the complex measures and its advantages were discussed in comparison to other widely applied approaches in his paper of health inequalities (Wagstaff et al., 1991a). The related details are provided in Chapter 3.

Table 2. Measurements applied in inequalities in access to water and sanitation (2015-2020)

No	Type of inequality	Within country	Between countries	Global inequality among peoples	Country focus	Causal vs Descriptive	Measures	Data	Author
1	geographic (spatial), economic inequalities	x			Brazil	D	Comparison of 5 measures made: simple disaggregation, Concentration coefficient and concentration curve, Dissimilarity index, Generalised Entropy measure and Atkinson´s index.	Census, NSO Brazil	Cetrulo T.B., Marques R.C., Malheiros T.F., Cetrulo N.M. (2020)
2	individual and group-related inequalities (race)	x			USA	C	OLS linear regression	Census housing, U.S.-ACS	Gasteyer S.P., Lai J., Tucker B., Carrera J., Moss J. (2016)
3	individual and group-related inequalities (health conditions)	x			Ethiopia, Wukro	C	Pearson's Chi-squares, Logistic regression	Primary data	Jimenez-Redal R., Holowko N., Almandoz J., Soriano J., Arregui F., Magrinya F.(2018)
4	individual and group-related inequalities (intersecting)	x	x		Latin America and the Caribbean	D	Simple linear regression	Census IPUMS project	Queiroz V.C., de Carvalho R.C., Heller L. (2020)

5	geographical (temporal)	x	x		Developing countries	D	Nonlinear trajectory	DHS, MICS, nationally representative household survey - JMP data	Fuller J.A., Goldstick J., Bartram J., Eisenberg J.N.S. (2016)
6	geographical (spatial)	x			India	D	5 different measures: simple disaggregation, adapted Gini coefficient, Dissimilarity index, Spatial correlation, Analysis of agglomerative hierarchical clusters	Census, India	Chaudhuri S., Roy M. (2017)
7	geographic (spatial), economic	x			India (rural)	C	Gini coefficient, Spatial correlation, Percentage point difference, a composite index developed was used to measure the effect.	Census, India	Chaudhuri S., Roy M., Jain A. (2020)
8	economic (income based)		x		Developing countries	C	Simple disaggregation, Simple linear regression	WHO coverage data, OECD CRC database	Cha S., Mankadi P.M., Elhag M.S., Lee Y., Jin Y. (2017)
9	economic (income based)		x		Developing countries	C	Adapted Gini-coefficient, Multivariate regression	JMP wealth quintile data, WGI-World Bank	Bayu T., Kim H., Oki T. (2020)
10	geographic (spatial), economic		x		Sub-Saharan Africa	D	Concentration index, frequency ratios, percentage point differences	MICS, DHS	Roche R., Bain R., Cumming O. (2017)
11	geographical (spatial)	x			Indonesia	D	WHO-the mean difference from mean (MDM), WHO-the weighted index of disparity (IDIS – W)	SUSENAS, Indonesia	Afifah T., Nuryetty M.T., Cahyorini, Musadad D.A., Schlotheuber A., Bergen N., Johnston R. (2018)
12	geographical (spatial)	x			Ethiopia	D	WHO-the mean difference from mean (MDM), WHO-the weighted index of disparity (IDIS – W)	EDHS, Ethiopia CSA, nationally, regionally representative	Azage M., Motbainor A., Nigatu D. (2020)
13	geographical (spatial)	x			Nepal	D	Complex survey design method, Pearson's Chi-squares, Simple regression	DHS Nepal survey	Wang C., Pan J., Yaya S., Yadav R.B., Yao D. (2019)

Source: Author’s own construct.

2.3.6 Concentration index as a preferred approach to socioeconomic inequality

The concentration index was preferred over other methods such as 'simple disaggregation'[9] and 'Gini coefficient and Lorenz Curve'[10] due to the following reasons according to Wagstaff et al., (1991). First, the former excludes other social groups as it compares only two groups. While the latter cannot reflect the socioeconomic dimension of inequalities, although all groups are accounted in its estimation Second, the advantages of the CI include straightforward interpretation, inclusiveness of all social groups, decomposability (as to the connecting variables in selection, for example, household wealth), and independency (change in income and size of population does not affect the inequality measure). Third, the concentration index offers greater accuracy in estimation. Fourth, the concentration index received a recognition by the experts in "Inequality-WASH research" that it is *the most appropriate measure available to date under the condition of the objectives that is to measure and communicate inequality easily*. In addition, it is valuable for the cross-country comparison to inform a progress towards the global goals as *that meets more principles of sustainability assessment*. (Cetrulo et al., 2020, pp. 1, 11). Last but not least, this approach perfectly fits the goal of the dissertation and datasets readily available for analysis. It can thereby allow a legacy of international efforts to monitoring of the global goals and relevant research. For these reasons, the concentration index approach was selected to construct the water inequality index.

2.3.7 Hypothesis

Drawing on the findings from what literature suggests, the following hypothesis -1 is deducted: *Water access inequality* is significantly positively associated with *diarrhea-specific-child mortality.*

[9] It is also named as pairwise comparison.
[10] These two methods go hand in hand in analytical applications as Lorenz curve is a graphical illustration of the Gini coefficient, therefore, I consider it as a set of measure.

2.4 Summary

Chapter 2 visits four key points which underpin the subsequent chapters and build a backbone of the dissertation. Section 2.1 highlighted relevance of the study by discussing health as a key factor in economic development and how development ideologies went through the waves of development to meet the contemporary ideologies in which how health as a research problem has been approached. In line with David Cutler, Angus Deaton and Lleras-Muney (2006) Section 2.2 provided the determinants of child mortality outcomes from a health economics perspective by relating each factor based on the key theoretical explanations driving the current debate of global child mortality.

Building on this conceptual framing, Section 2.3 highlighted the research gap (i); defined the concept of water access inequality from a welfare economics perspective (ii); clarified the underlying concepts of socioeconomic inequality from the different philosophical positions, which were often neglected in the empirical literature (iii); highlighted an economic transmission channel through which water access inequality may affect child mortality (iv); discussed the related empirical studies to provide a context (v); as well as inequality measures by reviewing the most relevant papers (vi).

We departed from the argument that water is an important factor in determining child health status despite a few contradicting studies. The contradicting view is not neglected, for example, (Akachi et al., 2018), instead it was examined which then led to a discussion as to why they maybe arrived at such the conclusion. Moreover, we find several weaknesses in the previous relevant studies focusing on water access inequality and the relationship between water access inequality and child health.

First, apart from conceptual clarification is missing, both studies (Bayu et al., 2017; Hasan and Alam, 2020) relied on cross-sectional design. Although, cross-sectional data is useful in exploring patterns, it is unable to explore trends.

Second, Although Cha and colleagues (2017). explored the global trend in water access inequality, they used repeated cross-sectional design, which is still limited in accounting for the changes happened over the year, and this shortcoming becomes even more significant in building an association or a causality.

Third, choice of a quantification strategy in measuring water access inequality has significant consequences, which could end up either underestimating or overestimating the unjust inequalities. Its policy consequences then could be immense. This was exactly the main reason why Concentration Index approach was adapted to the dissertation, instead of Human Opportunity Index underpinned by Equality of Opportunity theory, in conceptualizing and measuring water access inequality. For the same reason, we consider that Gini-coefficient approach used by Bayu et al., (2017) still has a limitation such as being unable to capture a socioeconomic dimension in inequality (Wagstaff et al., 1991a).

Fourth, we addressed the limitation of previous study (Local Burden of Disease WaSH Collaborators, 2020), which looked at the geographic inequalities in access to water affecting child mortality diarrhea. As acknowledged in their paper, socioeconomic aspect of inequality was not captured in their estimations, in turn, which becomes the key focus of our study.

Chapter 3 describes methodology applied in the empirical parts. First three limitations are addressed in Chapter 4; the last one is addressed in Chapter 5. In addition, we suggest a comparative case study to investigate child mortality effect of water access inequality by selecting 4 countries in Chapter 6 to complement the quantitative hypothesis testing.

Chapter 3

Methodology

3.1 Introduction

The thesis employs a mixed methods approach, utilizing both quantitative and qualitative analytical methods across three empirical chapters. These analyses are deductive in terms of reasoning. Chapters 4 and 5 primarily rely on quantitative analytical techniques. Chapter 4 constructs a new index of water access inequality and provides a descriptive 61 cross-country analysis. Chapter 5 focuses on testing the hypothesis - 1 through an econometric model specified in this chapter. Conversely, Chapter 6 adopts a qualitative approach to test the hypothesis - 2. It is executed through a two-stages approach. First stage selects two case studies that should be analyzed in-depth. Second stage compares the two selected countries through a paired comparison approach. Chapter 3 describes research design and methodology in the subsequent sections.

3.2 Research Goal, Objectives, Hypotheses

Goal

The dissertation project aims to address the gap identified in the literature by clarifying the theoretical/ conceptual background of both child mortality and water access inequality (i) and by generating robust empirical evidence on whether water access inequality is a significant determinant of child diarrhea mortality in the context of low-and-middle-income countries by applying a mixed methods approach (ii).

Objectives

To achieve this goal, we follow 4 mutually exclusive yet sequential set of objectives.

First, we aim to provide a theoretical/conceptual background of the project by setting a story for health and economic development through a political economy lens (i), clarifying the determinants of child mortality from a health economics perspective (ii), clarifying the concept of socioeconomic inequalities in water access from a welfare economics perspective (iii), highlighted a plausible economic transmission channel (iv), and selecting a preferred method to quantify water access inequality based on the review of relevant empirical literature (v).

Second, building on this background, we construct water access inequality index in order to reveal its global trend and patterns by assessing 61 countries (objective 2) between 2000 and 2017 (N=61 and t=18).

Third, we assess the likely effects of water access inequality on the two child mortality outcomes by utilizing an extended panel approach with Driscoll-Kraay standard error and the panel data constructed for 47 countries covering the period between 2000 and 2017 (N=47 and t=18). In doing so, we combine the datasets from own estimates of Chapter 4 and other international sources to construct a multi-country, multi-year panel.

Fourth, the last empirical analysis aims to assess how water access inequality affecs the ‘success’ and ‘failure’ of the efforts in reducing child diarrhea mortality in the cases to be selected by applying a comparative case study approach.

Hypotheses

Theoretical literature yields hypotheses-1, which is tested in Chapters 5, while hypothesis-2 is tested in Chapter 6.

H-1: *Water access inequality* is significantly positively associated with *child diarrhea mortality*

H-2: *Changes in water access inequality (WII)* are significantly associated with *changes in child diarrhea mortality (CDM)*

Sub-hypotheses:

H-2.1: Decrease WII – Success CDM

H-2.2: Increase WII – Failure CDM

H-2.3: Absence of progress WII - Success CDM, if
the absence of change in WII is due to the presence of a high initial coverage of water

H-2.4: Absence of progress WII - Failure CDM, if
the absence of progress in WII is due to the absence of improvement towards full coverage of water

3.3 Data and Variables

3.3.1. Data

By combining multiple datasets, we achieved to construct the multi-country panel. First, health related datasets are collected from Institute for Health Metrics and Evaluation (IHME), the key advantage of this dataset is being "new" and disaggregated by cause of mortality, age and gender among others. Second, in order to build a panel for water access inequality index, we sourced household water access data disaggregated by wealth quintiles from WHO/UNICEF – Joint Monitoring Program. The key advantage of JMP data is allowing an international comparison with the readily available datasets by including over 5000 national data sources[11]. Third, female-education data is collected from UNDP – Human Development Index datasets. Fourth, all socioeconomic variables are collected from World Bank – World Development Indicators. It provides important macro datasets for an international comparison in economic, social, and development research. In addition, to inform the qualitative analysis, we used WHO's Rota-vaccine data, however, it was not sufficient to include in the panel. When it comes to sample size, having the total number of observations at least 10 times than the number of variables included in the model (Szent-Iványi, 2012) is accepted in development studies. This condition meets well enough in our research as the panel consists of observations = 846 and datapoints = 13515.

[11] https://washdata.org/data/info/household

The estimation of the key explanatory variable – WII – is constructed based on the JMP datasets. It, thus, deserves a bit more elaboration. The water access is classified by 5 ladders reflecting the quality of water source and collection time. In our analysis, the category we analyzed is "basic water services". This classification is made by the Methodology 2017 update (WHO-UNICEF, 2018). Why "*basic water services"?* this is the second-best category reflecting water quality and collection time. We excluded the category of safely managed water services from our analysis due to unavailability of the disaggregated wealth quintile data on water[12]. There is no need to evaluate the magnitude of inequalities in the lower quality water services given the idea that these types of services are unwanted, consequently other categories are also excluded from the analysis.

The JMP datasets are estimated using DHS & MICS household survey. Water access expressed by wealth quintiles are produced by applying Principal Component Analysis (PCA) to build a wealth index by following Filmer & Pritchett (2001). It then used to aggregate water access coverage by the estimated wealth index into five wealth groups (WHO-UNICEF, 2018).

Table 3. The JMP service ladder for drinking water

Drinking Water Ladder	Definition
1.Safely managed	Drinking water from an improved water source that is accessible on premises, available when needed and free from faecal and priority chemical contamination
2.Basic	Drinking water from an improved source, provided collection time is not more than 30 minutes for a roundtrip including queuing
3. Limited	Drinking water from an improved source for which collection time exceeds 30 minutes for a roundtrip including queuing
4.Unimproved	Drinking water from an unprotected dug well or unprotected spring
5.Surface water	Drinking water directly from a river, dam, lake, pond, stream, canal or irrigation canal

Note: Improved drinking water sources are those that have the potential to deliver safe water by nature of their design and construction, and include piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water. Source: https://washdata.org/monitoring/drinking-water;

[12] It is still unavailable as of June 2023.

3.3.2. Variables

Building on the theoretical background extended in Chapter 2, we include the following determinants of child mortality caused by diarrhea in the empirical analyses: GDP per capita, Income inequality, Nutrition, Urbanization, Female education, Healthcare, and Treatment – ORS. These determinants are in line with the synthesis study of David Cutler, Angus Deaton and Lleras-Muney (Cutler et al., 2006). Since our key interest is accounting the distribution of water access, water access inequality (WII) came to the model as a key explanatory variable, instead of water. For the same reason, we include sanitation access inequality (SII) in the model as a control variable. Moreover, maternal health is suggested as a determinant in child mortality by Cutler and colleagues, yet we consider mother's health is captured by nutrition variable in our macro-analysis, as nutrition is associated with good health (Fogel, 1997). In addition, since we take the nutrition into account as a determinant, we should also control a nutritious status of children. Breastfeeding is known as the most nutritious food for infants and children, and associated with better nutritious status (Roberts et al., 2013). To capture this effect, we included breastfeeding variable in the analytical model.

Immunization variable is excluded from the empirical model due to the following reasons. First, our dependent variable is child mortality caused by diarrheal disease. Against diarrheal infection, there is only one vaccination available to date, which first launched in 2006 (World Health Organization, 2021). Despite its availability, Rotavirus vaccine is one of the relatively new and underutilized vaccines, therefore, panel data on coverage of rotavirus vaccine is not sufficiently enough. For this reason, it is excluded. To date, there is no study published that was able to observe the effect of Rotavirus vaccine in a cross-country panel design. All-cause-mortality studies that accounted for the effects of immunization were always included other key vaccines other than Rotavirus vaccine. However, these other routine vaccines are not protective towards diarrheal infection; therefore, these are also excluded from our analytical model.

Table 4. Variables and Data sources

No	Indicator	Source	Scale	Definition
Dependent variables				
1	U5MRD	IHME	log scale, Per 1000 live births	The probability (expressed as the rate per 1,000 live births) that children born alive will die before reaching the age of 5 years due to diarrheal disease.
2	U5MRD, female	IHME		
3	U5MRD, male	IHME		
4	IMD	IHME		The probability (expressed as the rate per 1,000 live births) that infant born alive will die before reaching the age of 1 year due to diarrheal disease.
5	IMD, female	IHME		
6	IMD, male	IHME		
Independent variable				
7	Water access inequality index (WII)	Own estimates using JMP data	log scale, ranges between -1 and +1	Concentration of population having access to (basic) water according to their relative wealth quintile. Which means disaggregated wealth quintile data of water (JMP) is used to aggregate water access inequality index (WII).
Control variables				
8	Sanitation access inequality index (SII)	Own estimates using JMP data	log scale, ranges between -1 and +1	Concentration of population having access to (basic) sanitation according to their relative wealth quintile. Which means disaggregated wealth quintile data of sanitation (JMP) is used to aggregate sanitation access inequality index (SII)
9	GDP per capita	World Development Indicators	log scale, per capita PPP (current international $)	Gross domestic product per capita using purchasing power parity rates, constant at 2017 international dollars
10	Gini index	World Development Indicators	log scale, 0-100, %	Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.
11	Female education	UNDP	log scale, Percentage of population	Percentage of the population ages 25 and older that has reached (but not necessarily completed) a secondary level of education.
12	Physicians density	World Development Indicators	Per 1000 people	Number of physicians per 1000 people. Physicians include generalist and specialist medical practitioners.

13	Health expenditure per capita	World Development Indicators	log scale, per capita PPP (current international $)	Current expenditures on health per capita in current US dollars. Estimates of current health expenditures include healthcare goods and services consumed during each year.
14	ORS coverage	IHME	log scale, Percentage	Coverage of oral rehydration solution (ORS)
15	Cereal yield	World Development Indicators	log scale, kg per hectare	Cereal yield, measured as kilograms per hectare of harvested land, includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains.
16	Urbanization	World Development Indicators	log scale, Percentage of population	Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division.
17	Breastfeeding exclusive	IHME	Percentage	Exclusive breastfeeding prevalence estimates among infants under six months of age

Data sources: Panel on WII and SII used the author's own estimations based on the data from JMP. Institute for Health Metrics and Evaluation (IHME), 2022a, 2022b, 2019; UNDP Human Development Reports, 2022; WHO-UNICEF, Joint Monitoring Program, 2021; World Bank. World Development Indicators (WDI), 2022a, 2022b, 2021a, 2021b, 2021c, 2021d

3.4 Concentration index as an aggregation method

This section is dedicated to explaining the methods used to quantify water access inequality, which is reported in Chapter 4. In doing so we used Concentration Curve and Concentration Index (Kakwani et al., 1997; O'Donnell et al., 2007; Wagstaff et al., 1991a). We borrowed the methods from the health inequality research in order to build Water Concentration Curve and to construct the Water Concentration Index, we name it as Water Access Inequality Index (WII). It measures the magnitude of inequality that can be compared across countries.

The concentration index quantifies the degree of socioeconomic inequality in a variable of interest across the entire wealth distribution instead of focusing solely on the two out of five quintiles. It also takes into account the relative size of the different asset-based divisions of the study population (Gwatkin et al., 2000, p. 79). Moreover, it can be applied not only to health variables (O'Donnell et al., 2007, p. 94), thus, can be applied to water variables. This approach is also recommended as a favorable measure to apply for cross-country evaluations in the water and sanitation research (Cetrulo et al., 2020). Prior explaining the aggregation method – the concentration index, we need to understand the concentration curve and then the concentration index because the latter is defined by the former.

3.4.1. Concentration curve

Concentration curve is simply an illustration of concentration index. It provides a complete picture of the distribution of health (or water access) among population relative to the living standard measured by the wealth index. It illustrates the share of health (or water access) indicator accounted by cumulative proportions of individuals in the population ranked from poorest to richest (Figure 5) (Kakwani et al., 1997; O'Donnell et al., 2007). It thereby can assess, in terms of health, whether child mortality is more unequally distributed to the disadvantaged poor population in one country than in another as defined by Wagstaff (2000), whether subsidies to the health sector are targeted toward the poor (O'Donnell et al., 2007, p. 83). Applying it to water access, the curve assesses whether water access is targeted toward the poor. In other words, extent to which water access is distributed among the poor.

The concentration curve plots the cumulative percentage of the health (or water access) variable on the Y-axis against the cumulative percentage of the population ranked by living standards (wealth quintiles) beginning with the poorest- Q1 and ending with the richest -Q5 on the X-axis (Figure 5). There is a 45-degree equality line that indicates perfect equality, while the concentration curve plots either above or below the line of equality. When health variable takes higher (lower) value, the position of the curve below (above) the equality line indicates the adverse effect, for example: child death, is more distributed among the poorer population. When the curve plots closer to the line of equality, it indicates a more equal situation, when the curve plots farther from the line of equality, it indicates an inequal situation. In the latter case, the magnitude of the health variable is more concentrated among the poor.

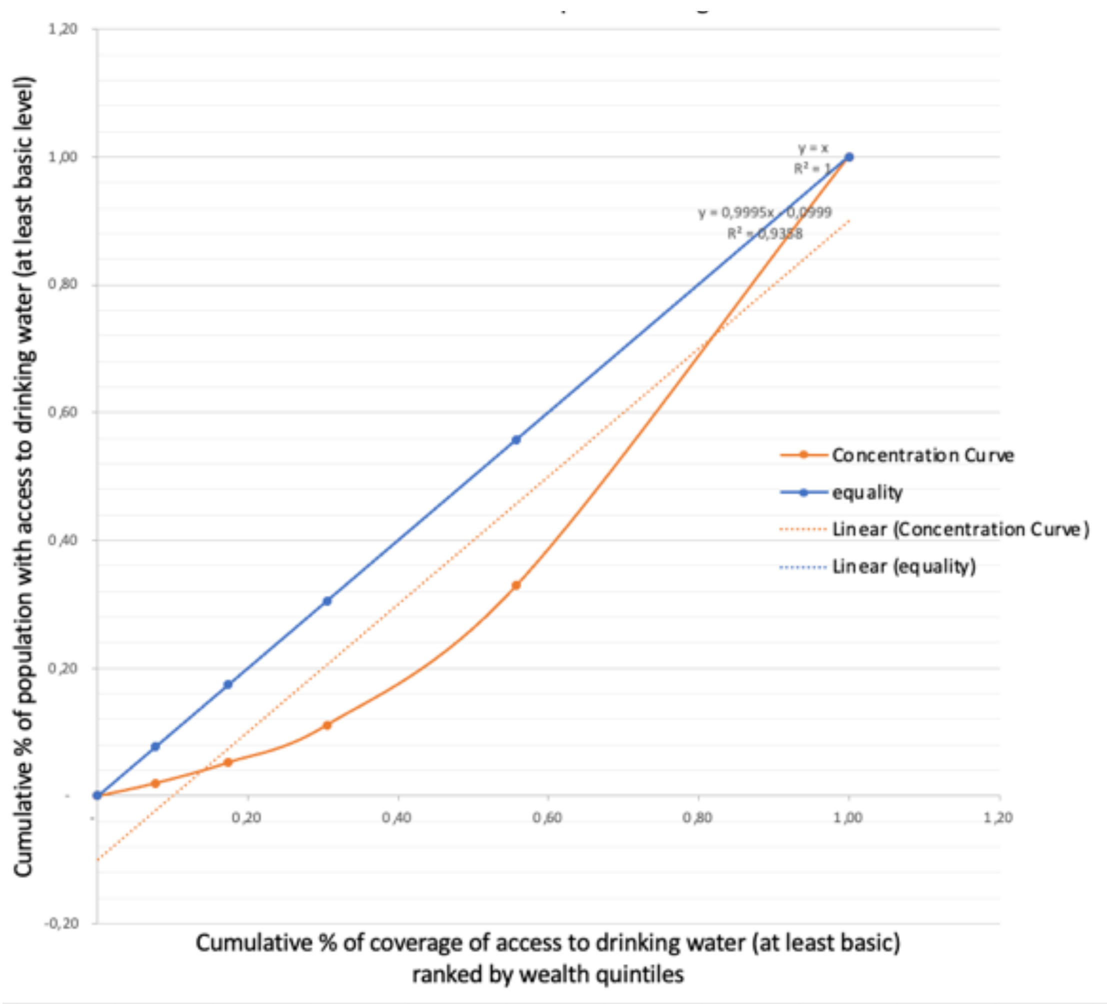
In terms of water access variable, this is slightly different depending on how the variable is defined. For example, we first need to see whether the variable takes a positive meaning or negative meaning. Depending on this, the direction of interpretation can differ. In water research, water access variable can have either positive or negative meaning depending on what level of water service the researcher is looking at. In our case, the variable takes *positive* meaning. For example, considering simplicity, the water access variable can be grouped into binary classification depending on the service levels - whether it is basic level or not. The water access indicator takes *'basic level'* for service under question, it takes *positive* meaning as the better the quality of water better the interested outcome. If the water access indicator takes '*not basic level'*, it takes *negative* meaning. In this case, the position of the curve and its interpretation rule follows exactly the same steps as of health research[13].

Since we are interested in evaluating extent to which basic water service is distributed among population, we take positive meaning, unlike ill-health inequality. This positive indicator of water access is highly dependent on economic status of the individual, therefore, if the positive access is widely available it is expected among the richer population. Therefore, the inequalities of water access measured by the concentration index more likely lies among the poorer population and expressed in positive values. Concentration curve, therefore, lies under the equality line. Then we interpret it in a way that water (access) inequality is concentrated among the poorer population (Figure X). This is how we interpret our analysis which is discussed in the following section.

For these reasons, it requires a careful planning from the researcher as the context of the indicator dictates a direction of interpretation of the index estimated. Unlike the context of our research variable, Cetrulo and colleagues (2020) looked at population without access to drinking water to apply the concentration index. This means they took negative meaning of the same variable in their analysis. However, it is also worth to note that whether looking at positive meaning of the variable does not really change the overall interpretation rule, instead, it could only require a more careful analysis in interpreting the numbers and the pattern of the water access concentration.

[13] For example, in health research, child mortality variable takes negative meaning. When a concentration index value of the variable (death) is negative, concentration curve goes under the equality line and expresses the death is more concentrated among the poorer population.

Figure 5. Concentration curve of Water Access Concentration:



Note: the cumulative proportion of population with access to water (at least basic) is on the Y axis, while the cumulative proportion of population ranked by wealth index (Q1-Q5: 0.20-1.0) lies on the X axis. Index towards -1 expresses distribution favors poor, the orange curve is concentration curve. The blue line is line of inequality, which appears when index equals to zero, expressing perfect equality. Area under curve is Concentration index, ranges from -1 to +1. Index towards +1 expresses distribution favors rich.

Source: Own construct based on the JMP datasets, World Bank – health inequality measure.

3.4.2. Concentration index

The concentration index (CI) quantifies the degree of socioeconomic inequality in a chosen variable. It is defined as twice the area between the concentration curve and the line of equality (the 45-degree line) (O'Donnell et al., 2007, p. 95). The value of CI ranges between -1 and 1. While, zero value denotes perfect equality (no difference between the rich and poor in terms of water access). Based on Kakwani et al., 1997 and O'Donnell et al., 2007 the following formula comes to estimate the water access inequality index when within-group variance is unknown:

Estimation and inference for ungrouped data (within-group variance is unknown)

$$CI = \frac{2}{N\mu}\sum_{i=1}^{n} w_i\, r_i - 1 - \frac{1}{N} \qquad (4.1)$$

where,

w_i is the water access

μ is its mean,

r_i =*i N* is the fractional rank of individual *i* in the living standards distribution, with *i* = 1 for the poorest and *i* = N for the richest.

For computation, a more convenient formula for the concentration index defines it in terms of the covariance between the health variable and the fractional rank in the living standards distribution as adapted from O'Donnell and colleagues. It is noted that CI_water (water access inequality) depends only on the relationship between the water variable and the rank of the living standards variable. However, the rank of the living standard is not the variation in the living standards. (O'Donnell et al 2007, p. 96).

Since our data to estimate concentration index is grouped as expressed by water access by quintiles, we focus on the grouped data case. In this case, the mean value of the coverage of water access (in the respective service ladder) variable is observed[14]. In the case of grouped data, the CI is computed based on the following formula (Fuller & Lury, 1977) as informed by (O'Donnell et al., 2007, p. 98).

[14] By the means of computation of standard errors of the concentration curve, it is methodologically possible to test whether there is a statistically significant difference between two concentration curves that may represent different health services (or water services), time periods, or countries according to O'Donnell and colleagues (2007). However, it is beyond the scope of the dissertation, therefore, this aspect of the concentration curve and concentration index is not covered.

Estimation and inference for grouped data

$$CI = (p_1L_2 - p_2L_1) + (p_2L_3 - p_3L_2) + \dots + (p_{T-1}L_T - p_TL_{T-1}) \quad (4.2)$$

where,

$\boldsymbol{p_T}$ is the cumulative percentage of the sample ranked by economic status in group t,

Lt is the corresponding concentration curve ordinate.

A standard error of the CI estimation in the case of grouped data was estimated on the basis of (Kakwani et al., 1997) that offers the following formula provided by (O'Donnell et al., 2007, p. 99)

$$R_t = \sum_{k=1}^{t-1} f_k + \tfrac{1}{2} f_t, \quad (4.3)$$

which is the cumulative proportion of the population up to the midpoint of each group interval.

The variance of the estimator of C is given by

$$\mathrm{var}(\hat{C}) = \frac{1}{n}\left[\sum_{t=1}^{T} f_t a_t^2 - (1+C)^2\right] + \frac{1}{n\mu^2}\sum_{t=1}^{T} f_t \sigma_t^2 (2R_t - 1 - C)^2 \quad (4.4)$$

where

n is the sample size,

$\boldsymbol{\sigma_t^2}$ is the variance of the water variable in the ***t***-th group,

μ is its mean

$$a_t = \frac{\mu_t}{\mu}(2R_t - 1 - C) + 2 - q_{t-1} - q_t,$$

and

$$q_t = \frac{1}{\mu}\sum_{k=1}^{t}\mu_k f_k, \tag{4.5}$$

which is the ordinate of $L_h(p)$, $q_0 = 0$, and $p_t = \sum_{k=1}^{t} f_k R_k$ based on the Kakwani & co-authors (1997) as explained in (O'Donnell et al., 2007, p. 98)

3.4.3. Application of concentration curve and concentration index to the case of Democratic Republic of Congo

In order to provide a better explanation of the method above specified, we estimated the water inequality index for the case of Democratic Republic of the Congo (Table 5) and illustrated it through the concentration curve (Figure 5).

Table 5. Water Access Coverage in Democratic Republic of the Congo, 2017 (within-group variance unknown)

Wealth group	*No. Of population with access to water*	*Cumul % population with access to water*	*R*	*Coverage rate of Water (Cov_wat)*	*Cumul % coverage*	*CI*	*q*	*a*	*$f \cdot a^2$*
Poorest	2.396.798	8%	0,039	14,723	2%	0,001	0,020	1,665	0,214
2nd	3.033.856	17%	0,126	18,636	5%	0,003	0,053	1,586	0,246
Middle	4.055.850	31%	0,240	24,913	11%	0,038	0,111	1,483	0,287
4th	7.844.398	56%	0,431	48,185	33%	0,228	0,329	1,207	0,368
Richest	13.766.954	100%	0,779	84,565	100%	0.000	1,000	1,106	0,541
Total /aver	31.097.855			55,793		0,271			1,655

Source: Own estimate based on Kakwini et al., 1997, O'Donnell et al., 2007

By applying the explanation of the CI on the book O'Donnell et al., 2007, we form the following explanation in our estimates of water access inequality index. As an example, we applied the method for the case of Democratic Republic of Congo (Table 5). It then applied each of 61 country in our sample. This is the case of within group variance unknown, assuming that there is no within-group variance and '*n*' needs to be replaced by 'T' in the denominator of the first term because there are in effect only T observations, not '*n*' (O'Donnell et al., 2007, p. 99). Assumption made for this estimate is that the within-group variances in water inequality are not known and are set to zero. To relax this assumption, the results show the values for each quintile of R, q, a, and fa^2 computed by substituting estimates for the parameters in the formula above. Also shown is the sum of fa^2 across the five quintiles. Substituting $\Sigma f \cdot a^2 = 1.655$, CI = 0.2710, and T = 5 into equation 4.4 that gives 0.0081 for the variance of the estimate of CI and a standard error equal to 0.0901. The t-statistic for CI is therefore 3.00. The value of CI of DR Congo is 0.2710. The positive value of concentration index[15] reflects the higher level of coverage for water access among richer population, which means the gap between poorer and richer population exist.

3.5 Panel analysis: Strategy, Specification, Tests

3.5.1 Transformation of data

The following strategy is employed in constructing the panel. We took all available data from each source. The period 2000 and 2017 reflects the period in which most data points are found. We then select those countries have at least two data point within the range of 2000 and 2017. To allow more balanced panel, missing data is interpolated. Interpolation was also used in previous similar studies (Anand and Bärnighausen, 2004; Jamison et al., 2016). Logarithmic transformation is made when necessary. Lagged health expenditure value was used considering the role of the variable in health outcomes in line with Hu and Mendoza (2013), given the idea that health expenditure impact comes later. Unlike Hu & Mendoza, we used female education variable without its lag, because our data reflects secondary education, not a literacy.

[15] In terms of health variable (U5MR), the negative concentration index reflects the higher mortality rates among poorer children. Here, again, we can remember back how the variable is described in water access research to interpret the meaning of CI estimated.

3.5.2 Panel Construct

Model specification

We construct a panel fixed effects regression model based on the (Greene, 2003). In this model each outcome variable is specified as a linear function of household water access inequality. For the period of 2000 and 2017, the model examines the child mortality effects of water access inequality. The analysis was carried out in STATA 17.0 software.

Our basic OLS model:

(1) $$Y_{it} = \beta_0 + \beta_1 \mathrm{WII}_{it} + \beta_2 \mathrm{X}_{it} + \varepsilon_{it}$$

Since there is possibly an unobserved variable but correlated with the key explanatory variable in our study, the OLS estimators of parameter can suffer from omitted variable bias. It is, therefore, necessary to take the fixed-effects model into the consideration. Because α_i embodies all the observable effects and specifies an estimable conditional mean (Greene, 2003, p. 285).

Fixed Effects model accounting for country-fixed effects:

(2) $$Y_{it} = \beta_0 + \beta_1 \mathrm{WII}_{it} + \beta_2 \mathrm{X}_{it} + \alpha_i + \varepsilon_{it}$$

Extended Fixed Effects model accounting for country-and-time-fixed effects:

(3) $$Y_{it} = \beta_0 + \beta_1 \mathrm{WII}_{it} + \beta_2 \mathrm{X}_{it} + \alpha_i + \gamma_t + \varepsilon_{it}$$

Applying (3) to the Extended Fixed effects Child Mortality Model:

(4) $$log(U5MRD_{it}) = \beta_0 + \beta_1\ log(WII_{it}) + \beta_2\ log(X1_{it}) + \beta_3(X2_{it}) + \alpha_i + \gamma_t + \varepsilon_{it}$$

Hereby, the Extended Fixed Effects Infant Mortality Model:

(5) $$log(\mathrm{IMD}_{it}) = \beta_0 + \beta_1\, log(WII_{it}) + \beta_2\, log(X1_{it}) + \beta_3(X2_{it}) + \alpha_i + \gamma_t + \varepsilon_{it}$$

where, $\mathrm{U5MRD}_{it}$ –under-five diarrhea caused child mortality rate,

IMD_{it} –diarrhea caused infant mortality rate,

i -country; t – time,

$\beta 0$ – intercept (i.e., value of $U5MRD_{it}/IMD_{it}$ when WII_{it} is zero),

$\beta 1$- coefficient expressing an extent to which effect of water access inequality on child mortality over time,

WII_{it} – Water access inequality index, computed in Chapter 4

$\beta 2$- coefficient expressing an extent to which effect of a vector of control variables on child mortality over time,

$X1_{it}$ – a vector of control variables, with log transformation, including Sanitation access inequality, GDP per capita, Gini index, Female education, Lagged Health Expenditure, ORS coverage, Cereal yield, Urbanization

$X2_{it}$ – a vector of control variables, without log transformation, including Physician density, Breastfeeding

α_i –a group specific constant term,

γ_t– time-fixed-effects,

ε_{it} – error term

Where appropriate, the variables are transformed into logarithmic values with the aim to normalize the data. Some control variables are not necessary to be transformed. For example, Physician density, Breastfeeding. These variables are therefore expressed by $X2_{it}$ in the Equations (4) and (5).

In addition, Driscoll – Kraay standard errors are applied to the models (4) and (5) in line with Hoechle (2007). By this extension, we addressed the presence of heteroskedasticity, cross-sectional dependence/ contemporaneous correlation, and serial correlation in our data. These problems are diagnosed and addressed in the manner extended in the section 3.5.3.

3.5.3 Diagnostic tests

We carried out seven sequential to diagnose our panel across child mortality models. First, Variance Inflation Factor (VIF) test was performed to see whether there is multicollinearity in the data since our model is multivariate. The mean value of VIF indicated 2.45 (Appendix: 2), which means 'safe' in terms of degree of multicollinearity, thus it is concluded that there is no significant multicollinearity in the data. The VIF threshold is considered problematic if the mean VIF >5, often times VIF >10 (James et al., 2013; Menard, 2002; Vittinghoff, 2012). Second, we tested whether time-fixed-effects is needed in the model. P-value was 0.0000 across models (Bartels, 2008). The results indicated that time-fixed-effects are necessary to include. Third, Random effects -GLS model was identified as the preferred model over OLS model by running Breusch-Pagan Lagrange Multiplier test (Baltagi et al., 2007; Greene, 2003, p. 298). Fourth, Pesaran test was performed to test whether there is cross-sectional dependence/contemporaneous correlation in the panel (De Hoyos and Sarafidis, 2006; Hoechle, 2007). As a result, we found that cross-sectional dependence/contemporaneous correlation is present. Fifth, Breusch-Pagan LM test of independence test was employed testing whether panel is serially correlated (Baum, 2000a; Greene, 2003). The result suggests the panel is serially correlated in all models. Six, Modified Wald test was performed to prove that there is groupwise heteroskedasticity is present in all regression models (Baum, 2000b; Greene, 2003). Furthermore, as the tests 4-6 proved that there is groupwise heteroskedasticity, cross-sectional dependence/contemporaneous correlation and serial correlation in the panel (Table 6), we would need to adjust the standard errors in our models to estimate the reliable results. To address this issue, we opted for the Driscoll–Kraay standard errors method suggested by Hoechle (2007) as it is robust when cross-sectional dependence is present in the panel. Finally, Hausman's Specification test was conducted to select an appropriate model between fixed-effects and random-effects model. The results suggest random-effects model is more appropriate to interpret the results.(Greene, 2003, p. 301) . Standard Hausman's specification is one of the specification tests used in the models with Driscoll–Kraay standard errors (Hoechle, 2007).

Table 6. Summary of the diagnostic test results

Diagnostics	1 Variance Inflation Factor test	2 Time fixed effets	3 Breusch-Pagan Lagrange Multiplier test	4 Pesaran test of cross-sectional dependence	5 Breusch-Pagan LM test of independence	6 Modified Wald test	7 Hausman specificaiton test
Purpose	Whether and extend to which multicollinearity is present	Whether we need time-fixed-effects in the model	Whether we need random effects model over OLS model?	Whether there is cross-sectional dependence/ contemporaneous correlation	Whether panel is serially correlated	Whether groupwise heteroskedasticity is present in FE regression model	Identify the preferred model
median VIF/P-value/abs, Model 1	2.45	0.0000	0.0000	0.0128/ 0456	0.0000	0.0000	0.2265
median VIF/P-value/abs, Model 2		0.0000	0.0000	0.0121/0.437	0.0000	0.0000	0.0000
median VIF/P-value/abs, Model 3		0.0000	0.0000	0.0145/0471	0.0000	0.0000	no difference
median VIF/P-value/abs, Model 4		0.0000	0.0001	0.0122/0.530	0.0000	0.0000	no difference
median VIF/P-value/abs, Model 5		0.0000	0.0000	0.0262/0.486	0.0000	0.0000	0.9997
median VIF/P-value/abs, Model 6		0.0000	0.0001	0.0109/0.550	0.0000	0.0000	no difference
Finding	ACCEPTABLE	YES	YES	YES	YES	YES	RE

3.6 Comparative case study approach

Comparative case study approach is utilized in our last empirical chapter, following the similar approach adapted in the upcoming political economy book edited by István Benczes (Benczes, 2023), in which I contributed Chapter 12 (Bulgamaa, 2023). Chapter 6 goes through two-stages analysis. It firstly selects the cases based on the thorough analysis from the pool of 61 countries in our sample, and then compared the selected cases through a paired comparison process to assess whether changes in water access inequality is associated with 'success' and 'failure' in the efforts reducing child diarrhea mortality.

3.7 Research ethics

As the datasets are from secondary sources openly distributed under the Creative commons license for the purpose of academic research. All individual level information involved in the survey data remain anonymous and no attempt is made to reveal them. Findings are presented as found. Any information used from others' works are referenced accordingly. There is no conflict of interest associated with the dissertation.

Chapter 4

Water Access Inequality Index: A Concentration Index Approach

4.1 Introduction

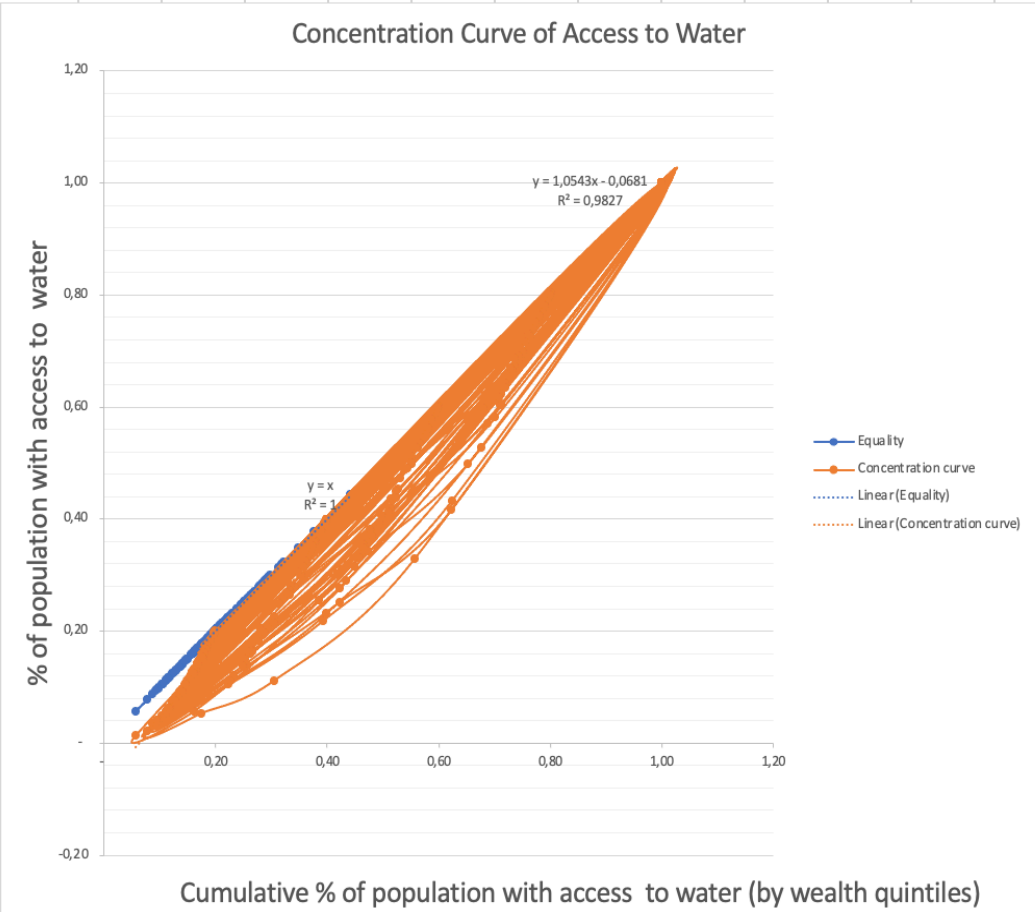
We departed from the finding that water is an important factor in determining child health status as reviewed in Chapter 2. We defined the concept of water access inequality as the extent to which inequalities in water access are related to indicators of socioeconomic status such as income/wealth from a welfarist perspective. This could reveal household water access inequalities due to socioeconomic conditions, which are camouflaged by coverage of water access. By addressing four limitations listed in the literature review (see: Conclusion of Chapter 2), concerning these studies (Bayu et al., 2020; Md Masud Hasan and Alam, 2020b; Local Burden of Disease WaSH Collaborators, 2020) , this chapter aims to quantify socioeconomic inequalities in water access by constructing a composite water access inequality index (WII) to facilitate cross-country comparisons across low- and middle-income countries over time. Building on the literature of concentration index and wealth index (Filmer and Pritchett, 2001; Kakwani et al., 1997; O'Donnell et al., 2007; Wagstaff et al., 1991a) the index is constructed by utilizing the wealth quintile data of basic water access from the WHO/UNICEF-JMP dataset covering 61 low-and-middle-income countries and the period between 2000 and 2017. We then ranked the countries in our sample according to their performance in reducing water access inequality by comparing the values of the base year to the values of the latest year.

4.2 Results: Water access inequality in an international comparison

4.2.1. Concentration curve of water access

Concentration index ranges from -1 to +1. A positive value indicates that the concentration of water access presents among richer population, while negative value indicates it among poor population. It also shows magnitude of inequality – the closer the zero, the greater the equality, the farther the zero, the opposite is true (greater the inequality). Moreover, the concentration curve (Figure 6) shows that the inequalities in access to at least basic drinking water in LMIC is predominantly concentrated among the richer population, therefore the curve gets the shape of under the equality line. The overall shape of the arrow shows that richer the population, closer the equality line, while poorer the population, the farther the equality line. This clearly indicates the poorer population have disadvantage in access to at least basic drinking water as compared to the richer counterparts.

Figure 6. Concentration Curve of water access in LMIC, 2017



Note: Own construct. Concentration curve of low-and-middle income countries from the JMP datasets (*n=61*). The inequality curve illustrates the concentration of water access inequality indices estimated from the JMP's wealth quintile data sets of 61 low-and-middle income countries. Under the equality line indicates the fact that access to basic water services concentrated on the rich.

The least equal top 5 countries, by 2017, were Democratic Republic of Congo CI=0.2705; Madagascar CI=0.2354; Ethiopia CI=0.2348; United Republic of Tanzania CI=0.2129; and Zambia CI=0.1797. On the contrary, the most equal top 5 countries, by 2017, were Paraguay CI= -0.0003; Ukraine CI= 0,0005; Jordan CI= 0,0008, Egypt, Armenia, Montenegro CI=

0,0012. These countries have 98-100% of coverage rate across the quintiles, in terms of at least basic drinking water services. These values express also the important differences among the countries. The Least equal countries are predominantly concentrated in the Sub-Saharan Africa, while the most equal countries are concentrated in the Europe & Northern America, in terms of SDG regions. (Figure 9, 10) It is also to note that there is a trend that the lower the income, higher the inequalities in access to drinking water and sanitation.

4.2.2. Water Access Inequality Index and International Ranking

Table 7. Change in Water Access Inequality – International Ranking as of 2017

Country	Rank 2017	WII 2017	WII 2000	Absolute change	Relative change %	Change compared to 2000	Income group	SDG Region
Paraguay	1	-0,0003	0,1362	- 0,1365	-100%	decreased	UM	LAC
Albania	2	0,0110	0,1611	- 0,1501	-93%	decreased	UM	ENA
Egypt	3	0,0012	0,0102	- 0,0090	-88%	decreased	LM	NAWA
Armenia	4	0,0012	0,0100	- 0,0088	-88%	decreased	UM	NAWA
Ukraine	5	0,0005	0,0038	- 0,0033	-86%	decreased	LM	ENA
Kazakhstan	6	0,0045	0,0271	- 0,0226	-83%	decreased	UM	CSA
Dominican Republic	7	0,0063	0,0316	- 0,0253	-80%	decreased	UM	LAC
Thailand	8	0,0037	0,0150	- 0,0113	-75%	decreased	UM	ESEA
Honduras	9	0,0115	0,0414	- 0,0299	-72%	decreased	LM	LAC
Bolivia (Plurinational State of)	10	0,0330	0,1027	- 0,0696	-68%	decreased	LM	LAC
Mongolia	11	0,0493	0,1433	- 0,0940	-66%	decreased	LM	ESEA
Viet Nam	12	0,0289	0,0745	- 0,0455	-61%	decreased	LM	ESEA
Bosnia and Herzegovina	13	0,0023	0,0058	- 0,0035	-60%	decreased	UM	ENA
Tajikistan	14	0,0638	0,1565	- 0,0928	-59%	decreased	Low	CSA
Malawi	15	0,0647	0,1438	- 0,0791	-55%	decreased	Low	SSA
Niger	16	0,1116	0,2371	- 0,1255	-53%	decreased	Low	SSA
Peru	17	0,0458	0,0959	- 0,0501	-52%	decreased	UM	LAC
Philippines	18	0,0296	0,0612	- 0,0317	-52%	decreased	LM	ESEA
Indonesia	19	0,0518	0,1045	- 0,0527	-50%	decreased	UM	ESEA
Ghana	20	0,0773	0,1552	- 0,0779	-50%	decreased	LM	SSA

Congo	21	0,0862	0,1647	- 0,0785	-48%	decreased	LM	SSA
India	22	0,0264	0,0490	- 0,0225	-46%	decreased	LM	CSA
Liberia	23	0,0739	0,1288	- 0,0548	-43%	decreased	Low	SSA
Gabon	24	0,0641	0,1070	- 0,0430	-40%	decreased	UM	SSA
Mali	25	0,1231	0,1971	- 0,0740	-38%	decreased	Low	SSA
Belarus	26	0,0019	0,0029	- 0,0011	-37%	decreased	UM	ENA
Nigeria	27	0,1477	0,2344	- 0,0866	-37%	decreased	LM	SSA
Kenya	28	0,1493	0,2354	- 0,0861	-37%	decreased	LM	SSA
Benin	29	0,0941	0,1450	- 0,0509	-35%	decreased	LM	SSA
Senegal	30	0,1170	0,1728	- 0,0558	-32%	decreased	LM	SSA
Colombia	31	0,0369	0,0506	- 0,0137	-27%	decreased	UM	LAC
Sierra Leone	32	0,1400	0,1913	- 0,0513	-27%	decreased	Low	SSA
Cameroon	33	0,1492	0,2003	- 0,0511	-26%	decreased	LM	SSA
Mauritania	34	0,1369	0,1817	- 0,0448	-25%	decreased	LM	SSA
Namibia	35	0,0995	0,1302	- 0,0307	-24%	decreased	UM	SSA
Zambia	36	0,1797	0,2335	- 0,0539	-23%	decreased	LM	SSA
Yemen	37	0,1237	0,1589	- 0,0352	-22%	decreased	Low	NAWA
United Republic of Tanzania	38	0,2129	0,2716	- 0,0587	-22%	decreased	LM	SSA
Tunisia	39	0,0307	0,0389	- 0,0082	-21%	decreased	LM	NAWA
Uganda	40	0,1742	0,2205	- 0,0463	-21%	decreased	Low	SSA
Togo	41	0,1700	0,2113	- 0,0413	-20%	decreased	Low	SSA
Ethiopia	42	0,2348	0,2902	- 0,0554	-19%	decreased	Low	SSA
Burundi	43	0,0719	0,0877	- 0,0158	-18%	decreased	Low	SSA
Nepal	44	0,0362	0,0438	- 0,0076	-17%	decreased	LM	CSA
Madagascar	45	0,2354	0,2776	- 0,0422	-15%	decreased	Low	SSA
Côte d'Ivoire	46	0,1239	0,1403	- 0,0164	-12%	decreased	LM	SSA
Nicaragua	47	0,0846	0,0938	- 0,0091	-10%	decreased	LM	LAC
Democratic Republic of the Congo	48	0,2705	0,2871	- 0,0166	-6%	decreased	Low	SSA
Burkina Faso	49	0,1287	0,1351	- 0,0064	-5%	decreased	Low	SSA
Pakistan	50	0,0333	0,0341	- 0,0008	-2%	decreased	LM	CSA
Bangladesh	51	0,0096	0,0096	- 0,0000	0%	no change	LM	CSA
South Africa	52	0,0568	0,0565	0,0003	0%	increased	UM	SSA
Turkey	53	0,0047	0,0047	0,0001	2%	increased	UM	NAWA

Angola	54	0,1611	0,1540	0,0071	5%	increased	LM	SSA
Zimbabwe	55	0,1597	0,1514	0,0083	5%	increased	LM	SSA
Rwanda	56	0,1255	0,1105	0,0150	14%	increased	Low	SSA
Lesotho	57	0,0939	0,0775	0,0165	21%	increased	LM	SSA
Jordan	58	0,0008	0,0005	0,0003	60%	increased	UM	NAWA
Jamaica	59	0,0226	0,0134	0,0092	69%	increased	UM	LAC
Montenegro	60	0,0012	N/A	N/A	N/A	N/A	UM	ENA
Maldives	61	0,0017	N/A	N/A	N/A	N/A	UM	CSA

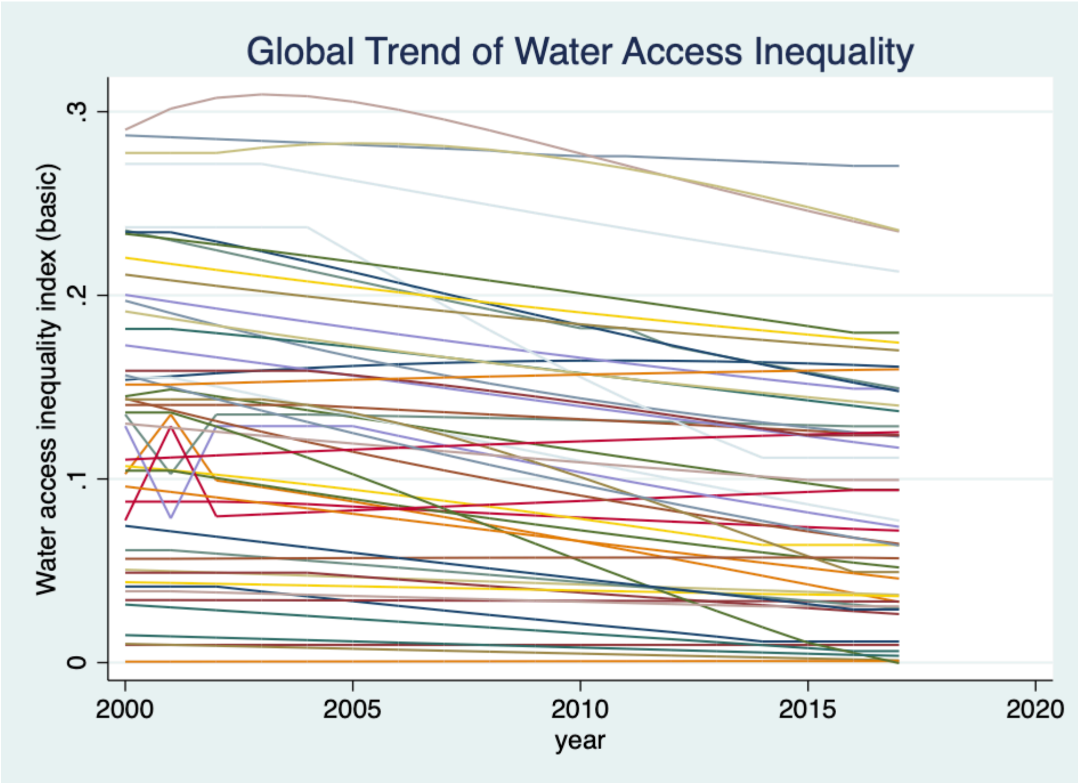
Source: Own construct based on the estimation of Water Access Inequality Index (WII). Data: WHO/UNICEF JMP. The countries are ranked starting from least to most inequal position in terms of (basic) water access. Income classification: UP – upper middle; LM – lower middle; Abbreviations reflect the following SGD regions:

LAC - Latin America & the Caribbean; ENA - Europe&Northern America;

NAWA - Northern Africa & Western Asia; CSA - Central & Southern Asia;

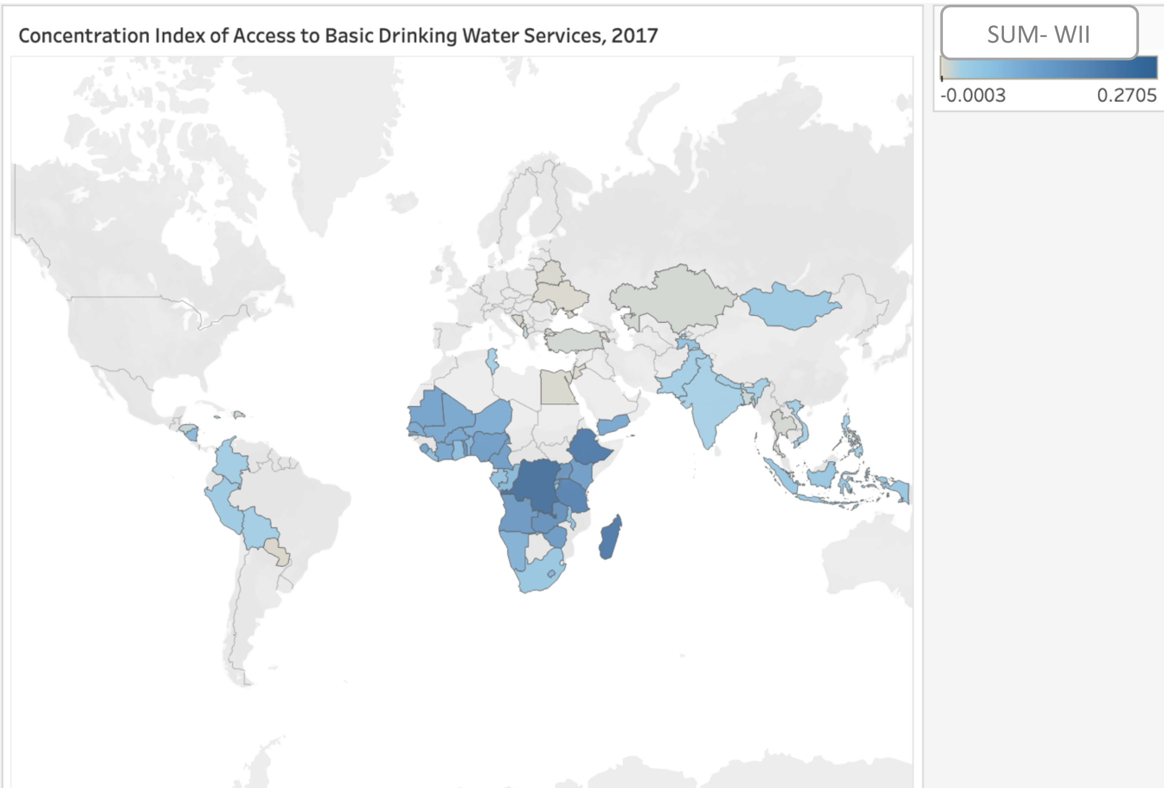
ESEA - Eastern & South-Eastern Asia; SSA - Sub-Saharan Africa

Figure 7. Trend of water access inequality across low-and-middle-income countries 2000-2017



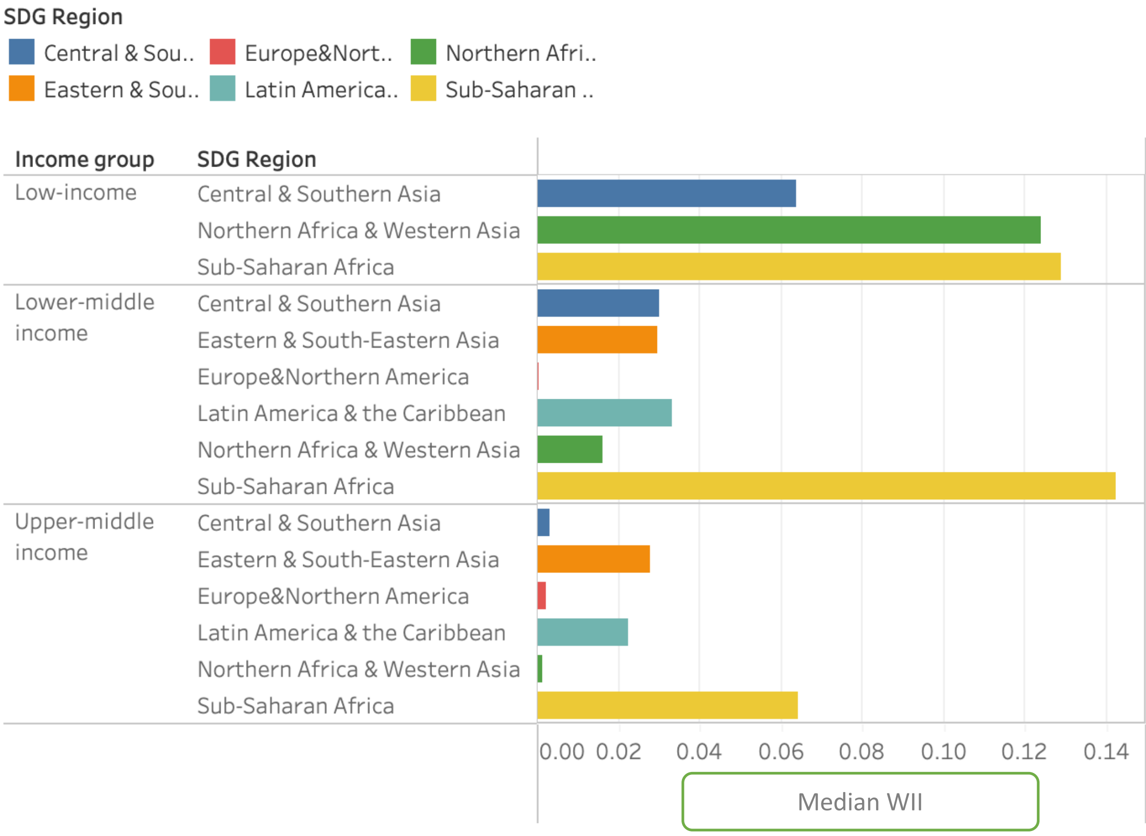
Source: Own construction. Data: own estimates using JMP datasets.

Figure 8. International Water Inequality Map 2017



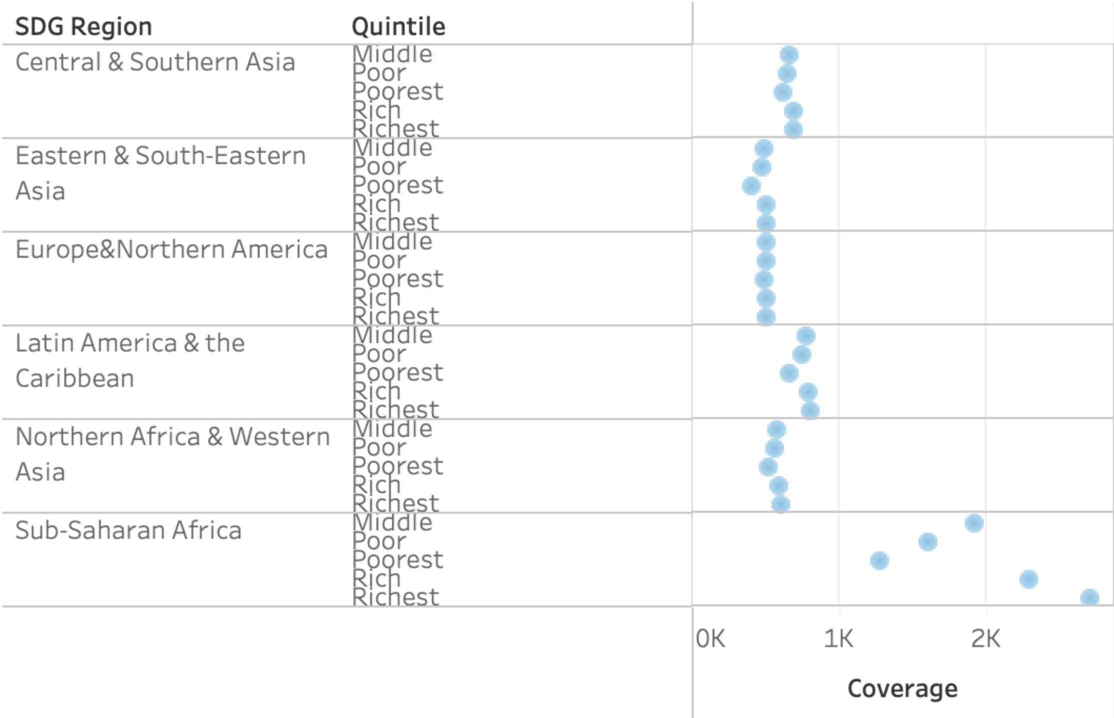
Note: Own construct. Water access inequality map of low-and-middle income countries from the JMP datasets (*n=61)*. The inequality map illustrates the concentration indices of water access inequality estimated from the JMP's wealth quintile data sets of 61 low-and-middle income countries. These countries are selected due to the datasets acquired from the other sources to create a combined dataset for the regression analysis.

Figure 9. The state of water access inequality across country income groups and SDG regions as of 2017



Note: Own construct. Median WII denotes average Water Access Inequality Index reflecting the distribution of water access between countries. The countries are grouped by their income levels and regions. The higher the value more the inequalities. Positive value indicates the access is concentrated among the richer population.

Figure 10. Water coverage by wealth quintiles - SDG regions, 2017



Note: Own construct. Coverage of water access by wealth quintiles in low-and-middle income countries based on the JMP datasets (*n=61*).

4.3 Summary

The chapter constructed the water access inequality index (WII), mapped the countries in terms of the state of water access inequality by 2017, and ranked these countries by their performance in averting water access inequality as of 2017 in comparison to 2000. To this end, we applied concentration index method borrowing from health inequality research as a robust complex approach to capture socioeconomic inequality and used JMP data on basic water access disaggregated by wealth quintiles.

The findings suggest that water access inequality prevails disproportionally across the world. The highest inequal region was Sub-Saharan Africa, followed by Latin America, while the least inequal region was Europe and North America. Moreover, the progress towards increasing coverage in countries were ended up increasing inequality in some countries, although it decreased inequality in most places. In terms of inequality reduction, the most 5 successful countries were Paraguay, Albania, Egypt, Armenia and Ukraine with the rate between 86-100% of reduction by 2017 compared to the level of 2000, whilst the least successful countries were Zimbabwe, Rwanda, Lesotho, Jordan, and Jamaica where WII actually increased by 5-69%.

This study is unique in several ways. First, it is the first empirical study observed socioeconomic inequality in water access using JMP datasets and concentration index method across large *N* countries covering multiple regions. Although Bayu et al., (2020) studied water access inequality using JMP data, they applied Gini index, which is limited as it does not capture socioeconomic aspect (Wagstaff et al., 1991). While Roche et al., (2017) applied the concentration index to the study with the DHS & MICS datasets to quantify the case of Sub-Saharan Africa. Second, we built a panel of water access inequality covering 61 countries and the period between 2000 and 2017 so that it would allow to further investigate the causes and consequences of water access inequality. Third, we observed the changes in WII between the base-year and the most recent year, which was not the case for any of the mentioned studies (Bayu et al.,2020; Roche et al., 2017).

These findings further suggest several important research directions. *First,* it asks whether water access inequality matters for child mortality caused by diarrhea as much as water access itself. *Second*, whether an effect of water access inequality was consistent on child diarrhea mortality given that water access inequality decreased in most countries despite few exceptions.

Third, why water access inequalities increased in some countries, while others managed to decrease it**.** *Fourth,* a general pattern emerged from the analysis is that access to adequate water services is often concentrated among the better off population rather than the poorer population as shown by the Water Access Concentration Curve, which, in turn, reveals the current state of the patterns of infrastructure coverage in the countries under scrutiny. This calls for an attention on the distribution of water related investments in order to reveal whether the WASH investments are really helping the poor. This is then about whom to benefit and whom to neglect from the distribution of water investment, that is often funded by international development community within the framework official development assistance (ODA) in the LMICs. Bayu et al., (2020) highlighted a need to study the effect of external fund absorption on WASH inequalities. However, absorption of fund is about how well the money is transmitted to a certain project. It does not really reveal who really benefits from that resource. Therefore, investigating what projects funded by WASH aid seems important to reveal whether development aid really helping the poor.

Chapter 5

The Effects of Water Access Inequality on Child Diarrhea Mortality: A Panel Approach

5.1 Introduction

Building on Chapters 2 and 4, this chapter aims test whether and extend to which water access inequality matters for child mortality caused by diarrhea, particularly in low-and-middle income countries (LMICs). The chapter solely focuses on the LMICs due to the reason that lacking access to adequate water and high child mortality levels are both the symptoms of poverty and the most pressing development challenges in this part of the world. Framed by Chapter 2, we hypothesize that water access inequality is significantly positively associated with child diarrhea mortality. Exploiting all available and relevant data and the estimates provided by Chapter 4, we managed to build a 47-country 18-year panel covering the period between 2000 and 2017 to allow an extended fixed-effects analysis. The Chapter 5 is then organized as follows. It starts with the results of the descriptive analysis, continues with the core results, and finally, it provides discussion and chapter conclusion.

5.2 Results: Descriptive statistics

This chapter presents the econometric analysis of combined panel data from 49 countries covering the period between 2000 and 2017, constituting 882 observations. Diarrhea-specific child mortality and infant mortality models were constructed. Therefore, the left-hand side of the models includes the dependent variables: child mortality diarrhea age under 5 (both genders), infant mortality diarrhea (both genders). On the right-hand side, the key explanatory variable is the water access inequality index, alongside the control variables such as sanitation access inequality index, GDP per capita, Gini coefficient, female education, physician per capita, lagged health expenditure, cereal yield, urbanization, breastfeeding, and oral rehydration salt (ORS). Missing data was interpolated where appropriate. Logarithmic transformations were applied when appropriate. On average, the child mortality rate per 1000 live births is 4.7%, while the infant mortality rate is 5.8%, indicating a higher level than the child mortality rate (Table X.)

Table 8. Descriptive Statistics: “water access inequalities” and child diarrhea mortality in LMICs between 2000 and 2017

Variables	Number of Observations	Mean	Std. Dev.	Min	Max
Log Child mortality Diarrhea age under 5 (both gender)	882	4.753425	1.429862	0.4945487	7.193156
Log Infant mortality Diarrhea (both gender)	882	5.833254	1.324479	1.751437	7.980045
Log Child mortality Diarrhea age under 5, female	882	4.673948	1.417089	.2804711	7.170364
Log Child mortality Diarrhea age under 5, male	882	4.808299	1.462222	.4724673	7.214425
Log Infant mortality Diarrhea, female	882	5.75171	1.315083	1.55965	7.759265
Log Infant mortality Diarrhea, male	882	5.890684	1.35385	1.733861	8.15403
Log Water access inequality	881	-2.560319	1.158706	-7.559643	-1.172971
Log Sanitation access inequality	875	-1.979109	0.9935179	-7.257913	-1.178071
Log GDP per capita	882	8.054603	0.866591	6.075522	9.765544
Log Gini	882	3.710634	0.1936801	2.848778	4.171306
Log Female education	845	3.040361	0.9273345	-1.07881	4.53582
Physician per capita	882	0.5966671	0.7658381	-0.0208	4.1764
Lagged log of health expenditure	833	5.013747	0.9200778	1.936089	7.012798
Log cereal yield (%)	882	7.423639	0.6552441	5.420978	8.930123
Breastfeeding exclusive 6 months	882	3.681523	0.1889779	0.030471	0.876757
Log Urbanization	882	0.3620886	0.4950067	2.109728	4.508075
Log ORS	882	3.556487	0.4517916	1.934106	4. 42657
Year	882			2000	2017
Country	882			1	49

Source: Own construct.

Table 9. The list of countries in the sample

	Country	Years available		Country	Years available
1	Angola	18	25	Namibia	18
2	Bangladesh	18	26	Nepal	18
3	Benin	18	27	Niger	18
4	Bolivia (Plurinational State of)	18	28	Pakistan	18
5	Burkina Faso	18	29	Peru	18
6	Burundi	18	30	Philippines	18
7	Côte d'Ivoire	18	31	Rwanda	18
8	Cameroon	18	32	Senegal	18
9	Colombia	18	33	Sierra Leone	18
10	Democratic Republic of the Congo	18	34	Tajikistan	18
11	Dominican Republic	18	35	Togo	18
12	Egypt	18	36	Uganda	18
13	Ethiopia	18	37	United Republic of Tanzania	18
14	Gabon	18	38	Viet Nam	18
15	Ghana	18	39	Zambia	18
16	Honduras	18	40	Zimbabwe	18
17	India	18	41	Mongolia	18
18	Indonesia	18	42	Mauritania	18
19	Jordan	18	43	Paraguay	18
20	Kenya	18	44	Thailand	18
21	Lesotho	18	45	Tunisia	18
22	Liberia	18	46	Yemen	18
23	Malawi	18	47	South Africa	18
24	Mali	18		Total	846

Source: Own construct. Madagascar and Nigeria are omitted in the regression because there is not, at least, one variable for female education 1 variable for our sample. Due to lagged health expenditure variable, some data is also omitted. This yields *N=795* observations across 17 variables, which then equivalent to 13515 data points.

5.3 Regression results: Water access inequality and diarrheal mortalities

Whether water access inequality is associated with child mortality? Figure 11 illustrates the relationship between water access inequality and child and infant mortality outcomes. On average, a positive correlation is observed between these variables, despite a few outliers. As water access inequality increases, so does the mortality rate. This pattern remains consistent when examining child and infant mortality outcomes disaggregated by gender in sensitivity analyses.

Moving to the regression results, we present the findings of the 18 mortality models in Tables 5.3-5.8. We employed Pooled ordinary least squares (OLS), Fixed effects, and Random effects models in Tables 5.3-5.5, and Fixed effects and Random effects models with Driscoll-Kraay standard errors in Tables 5.6 and 5.7, which provide the primary evaluation results. In Table 5.8, the results of sensitivity analyses are reported. The explanatory power of the models is high, in particular, the OLS models are 64-69% (R-squared), the FE models are 87-88% (R-squared), the RE models are 54-88% (R-squared) and 97-99% (rho). Overall, the results demonstrate a high level of consistency across the models.

We examined the direction of the relationships. In line with the relevant literature, the associations across child (and infant) mortality and predictors such as water access inequality, sanitation access inequality, and income inequality are *positive*. This suggests that inequality in these key determinants of child mortality contributes to higher child mortality rates. On the contrary, the associations across child (and infant) mortality and predictors such as GDP per capita, female education, physician density, health expenditure, treatment (oral rehydration salt), percentage of cereal yield, urbanization, and breastfeeding are *negative*. These factors are expected to have a protective (or curative) effect against child mortality. Therefore, reduction in factors that are positively and significantly associated with mortality and improvement in factors that are negatively and significantly associated with mortality would potentially lead to a decline in child and infant mortality rates. Therefore, we examined each predictor.

Holding all other factors constant, the key explanatory variable of interest, water access inequality, indicates a significant influence on both child and infant mortality across models

(Table 10,11,12), except for the infant mortality fixed effects model (Table 11). However, these results may be biased due to the problems of groupwise heteroskedasticity, cross-sectional dependence/contemporaneous correlation, and serial correlation in the panel data. To address these issues, we applied the Driscoll–Kraay standard errors method. The results from the adjusted models support that water access inequality is significantly positively associated with child mortality outcomes across mortality models. Since the Hausman's specification test suggested a random-effects model for interpretation, the core findings are reported from the random-effects models with Driscoll-Kraay standard errors (Table 14). Hence, our hypothesis is supported with a confidence interval between 95% and 99% (Table 13, 14).

Precisely, a one percent decrease in water access inequality averts child mortality age under 5 caused by diarrhea by 9.6 percent per 1000 live births, and infant mortality caused by diarrhea by 6.7 percent per 1000 live births. It implies that as children grow older, the risk of infection may increase, as their exposure to infection routes is increased. Infants are fully dependent on their mothers, while older kids, for example, a 4-year-old, can engage in activities independently, potentially increasing their exposure to diarrheal infection sources and contributing to a higher risk of infection.

We included sanitation access inequality as a control variable in our analysis of diarrheal child and infant mortality outcomes. Although not reported in the dissertation, as it is not a focus of our research, this variable is separately estimated for the panel analysis conducted in this Chapter. While its effect showed significance in the fixed and random effects models (Table 11, 12) and the fixed effects model with Driscoll-Kraay standard errors (Table 13), the significance is not retained in the baseline and adjusted models with Driscoll-Kraay standard errors (Table 10, 13, 14). This suggests that the role of sanitation access inequality is insignificant. It further leads to ask "Why?". One plausible explanation could be the small difference between the rich and poor in terms of sanitation access, given that basic sanitation coverage has been much less scaled up in comparison to water access coverage in the past decades.

Income per capita, expressed by GDP per capita, PPP (current international $), has a statistically significant negative impact on both child and infant mortality. The significance level is at a 99% confidence interval. Specifically, a one percent increase in GDP per capita leads to a reduction of 33.9 percent per 1000 live births in child mortality under the age of 5 caused by diarrhea, and a reduction of 32.8 percent per 1000 live births in infant mortality caused by diarrhea.

The distribution of income is significantly and positively associated with child mortality outcomes, similar to income per capita. A one percent decrease in income inequality is estimated to potentially reduce the probability of a child dying from diarrheal disease by approximately 44 percent per 1000 live births and the probability of an infant dying from diarrheal disease by roughly 39.4 percent per 1000 live births.

As anticipated, female education (measured as the percentage of female population with at least some secondary education) exhibits a statistically significant negative association with both child and infant mortality outcomes. Precisely, female education can avert 8.8 percent of child mortality age under 5 attributable to diarrhea and 5.2 percent of infant mortality caused by diarrhea per 1000 live births, respectively. This suggests that more educated mothers are more likely to adopt improved hygiene practices and implement essential preventive and curative measures for their children compared to less educated mothers, and this effect is stronger for children age under 5.

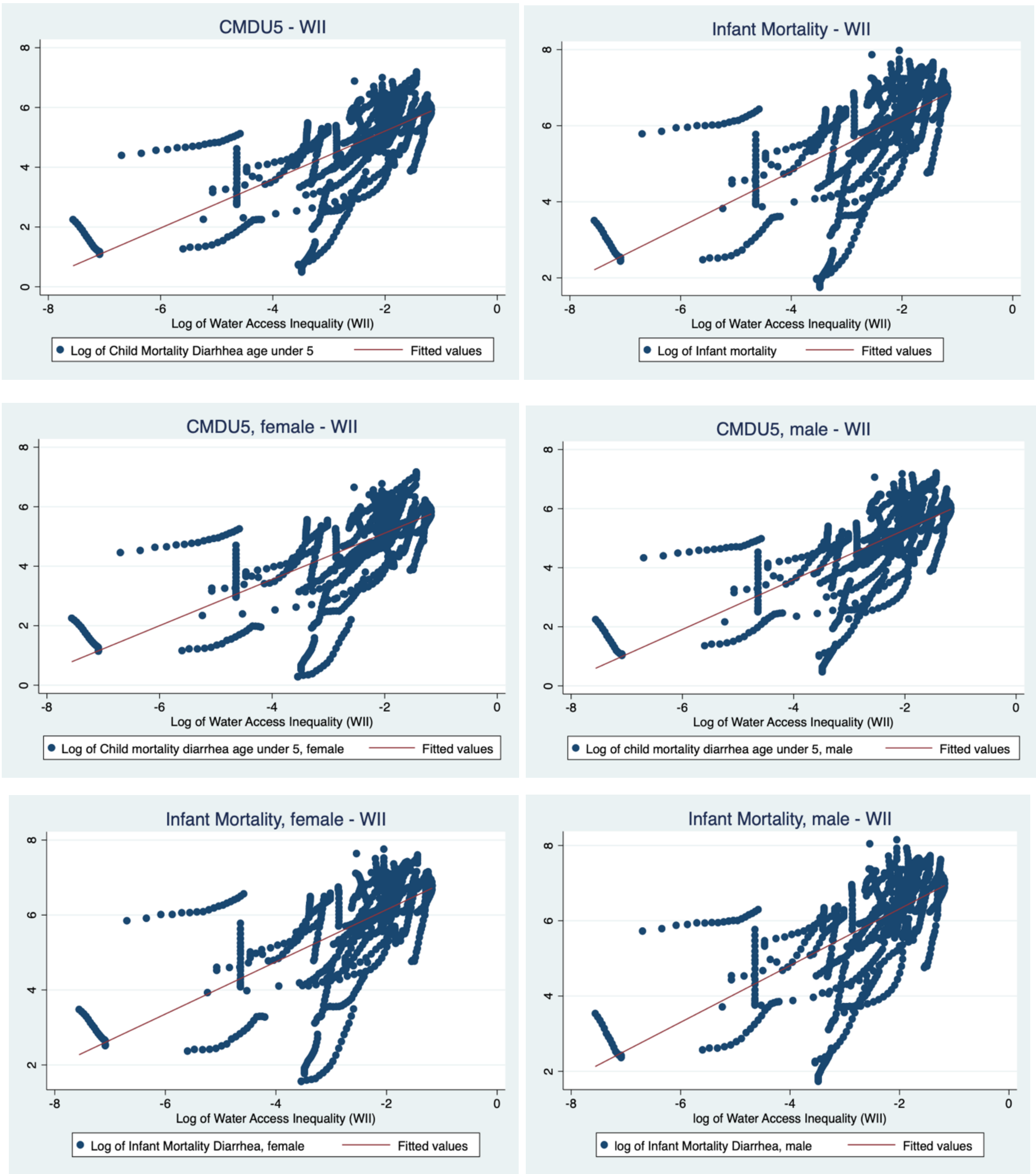
To capture health care effect, we included both lagged health expenditure per capita PPP (current international $) and number of physicians per 1000 people in the mortality models. Although direction of the association was in line with the expectation, health expenditure shows no significant negative association on both child and infant mortality outcomes across most mortality models. On the contrary, physician density was significant across all mortality models. In other words, a one percent increase in physician density reduces child mortality under age 5 caused by diarrhea by 7.4 percent per 1000 live births, while the same reduction effect is possible for infant mortality caused by diarrhea by 9.4 percent per 1000 live births in low-and-middle income countries.

In an effort to account for the effect of a medical treatment for diarrheal disease, oral rehydration salt (ORS) was included in the model. An expected negative direction of its effect was present in the results, its significance is lost across models except for OLS models. This suggests that availability of the treatment does not equate with a usage of the treatment. Perhaps, raising an awareness about this cheap and effective treatment for the mothers may result in better usage of the treatment when needed.

As a proxy to nutrition variable, we considered cereal yield (kg per hectare) for mothers and breastfeeding prevalence 6 month (%) for children as there is a relationship between maternal and child health. Both factors show expected ‘negative’ sign in our preferred model (Table 14). We found the effect of cereal yield on child and infant mortality was significant, on average, 24.5 percent reduction of child mortality and 22.7 percent infant mortality per 1000 live births were attributable to cereal yield. Yet, breastfeeding was not significant. One possible explanation about the significance maybe related to data. Breastfeeding data attributes an exclusive feeding of babies for 6 months. Which means that babies having both breastfeeding and additional feeding was excluded.

Urbanization was significantly and negatively associated with infant mortality in low-and-middle-income-countries, on average, 29.7 percent of diarrheal infant mortality reduction per 1000 live births is attributable to urbanization. Yet its association with diarrheal child mortality was not significant. One possible explanation on the negative association is that urban residency, on average, is associated with a better access to vital infrastructure such as water and sanitation access compared to rural residency in low-and-middle-income countries. This negative association is also enabled by creation of new cities rather than the increases in urban population growth. Even urban population growth does not solely imply contributing factor to child mortality, as only excess population growth causes such effect, i.e., positive association.

Figure 11. Linear projection: the relationship between diarrheal child mortality and water inequality index; diarrheal infant mortality and water inequality index



Note: Own construct. Scatter plots for key mortality outcomes and water access inequality (WII) levels. Standard errors in parentheses. * p<.05; ** p<.01; *** p<.001.

Sample 47 countries, 2000-2017. Source: WHO/UNICEF- JMP; IHME -Global Burden of Disease Study 2019 Results; WORLD BANK - World Development Indicators.

Table 10. Diarrhea Mortality - Baseline Models accounting for the effects of water access inequality. **Standard errors in parentheses.**

Variables	(1) Child mortality diarrhea	(2) Infant mortality diarrhea
Models	OLS-1	OLS-2
log_water access inequality	0.244***	0.233***
log_sanitation access inequality	0.034	0.027
log_GDP per capita	-0.075	-0.055
log_GINI	0.271	0.201
log_Female Education	-0.216***	-0.091
Physician density	-0.614***	-0.632***
log_Health Expenditure per capita (t-1)	-0.376***	-0.257**
log_ors	-0.220**	-0.164*
log_cereal	-0.223***	-0.246***
log_urbanization	0.256*	0.089
Breastfeeding	-0.074	-0.116
year		
2002	-0.050	-0.067
2003	-0.109	-0.132
2004	-0.156	-0.191
2005	-0.170	-0.222
2006	-0.194	-0.262
2007	-0.221	-0.306
2008	-0.227	-0.330
2009	-0.265	-0.374*
2010	-0.297	-0.411*
2011	-0.309	-0.430*
2012	-0.317	-0.447**
2013	-0.326	-0.468**
2014	-0.315	-0.469**
2015	-0.361*	-0.516**
2016	-0.379*	-0.537**
2017	-0.382*	-0.545**
Constant	9.667***	10.528***
Country	*47*	*47*
N	*795*	*795*
R2	*69%*	*64%*

Note: Sample 47 countries, 2000-2017. Standard errors in parentheses. * p<.05; ** p<.01; *** p<.001. Source: WHO/UNICEF- JMP; IHME -Global Burden of Disease Study 2019 Results; WORLD BANK - World Development Indicators.

Table 11. Diarrhea Mortality - **Fixed Effects** Models accounting for the effects of water access inequality. **Standard errors in parentheses.**

Variables	(3) Child mortality diarrhea	(4) Infant mortality diarrhea
Models	FE-1	FE-2
log_water access inequality	0.069*	0.045
log_sanitation access inequality	0.053*	0.050*
log_GDP per capita	-0.319***	-0.318***
log_GINI	0.454***	0.402***
log_Female Education	-0.072*	-0.042
Physician density	-0.062**	-0.084***
log_Health Expenditure per capita (t-1)	-0.075**	-0.049
log_ors	0.003	-0.003
log_cereal	-0.245***	-0.226***
log_urbanization	-0.115	-0.262
Breastfeeding	0.039	0.007
year		
2002	-0.061*	-0.063*
2003	-0.120***	-0.120***
2004	-0.168***	-0.169***
2005	-0.195***	-0.202***
2006	-0.228***	-0.238***
2007	-0.274***	-0.287***
2008	-0.303***	-0.321***
2009	-0.351***	-0.370***
2010	-0.406***	-0.422***
2011	-0.444***	-0.459***
2012	-0.477***	-0.491***
2013	-0.509***	-0.525***
2014	-0.531***	-0.548***
2015	-0.580***	-0.592***
2016	-0.611***	-0.620***
2017	-0.612***	-0.618***
Constant	9.027***	10.462***
Country	*47*	*47*
N	*795*	*795*
R2	*88%*	*88%*

Note: Sample 47 countries, 2000-2017. Standard errors in parentheses. * p<.05; ** p<.01; *** p<.001. Source: WHO/UNICEF- JMP; IHME -Global Burden of Disease Study 2019 Results; WORLD BANK - World Development Indicators.

Table 12. Diarrhea Mortality - **Random Effects** Models accounting for the effects of water access inequality. **Standard errors in parentheses.**

Variables	(5) Child mortality diarrhea	(6) Infant mortality diarrhea
Models	RE-1	RE-2
log_water access inequality	0.096***	0.067*
log_sanitation access inequality	0.066**	0.060**
log_GDP per capita	-0.339***	-0.328***
log_GINI	0.441***	0.394***
log_Female Education	-0.088**	-0.052
Physician density	-0.074**	-0.094***
log_Health Expenditure per capita (t-1)	-0.073**	-0.047
log_ors	-0.006	-0.010
log_cereal	-0.245***	-0.227***
log_urbanization	-0.187	-0.297*
Breastfeeding	-0.003	-0.035
year		
2002	-0.057*	-0.061*
2003	-0.114***	-0.117***
2004	-0.159***	-0.164***
2005	-0.183***	-0.195***
2006	-0.211***	-0.228***
2007	-0.254***	-0.275***
2008	-0.279***	-0.306***
2009	-0.323***	-0.353***
2010	-0.374***	-0.402***
2011	-0.408***	-0.436***
2012	-0.436***	-0.465***
2013	-0.463***	-0.496***
2014	-0.480***	-0.515***
2015	-0.526***	-0.557***
2016	-0.553***	-0.583***
2017	-0.552***	-0.580***
Constant	9.662***	10.836***
Country	*47*	*47*
N	*795*	*795*
R2	*88%*	*87%*

Note: Sample 47 countries, 2000-2017. Standard errors in parentheses. * p<.05; ** p<.01; *** p<.001. Source: WHO/UNICEF- JMP; IHME -Global Burden of Disease Study 2019 Results; WORLD BANK - World Development Indicators.

Table 13. Diarrhea Mortality - **Fixed Effects** Models accounting for the effects of water access inequality. **Driscoll-Kraay standard errors**

Variables	(7) Child mortality diarrhea	(8) Infant mortality diarrhea
Models	FE-3	FE-4
log_water access inequality	0.069***	0.045**
log_sanitation access inequality	0.053*	0.050
log_GDP per capita	-0.319**	-0.318**
log_GINI	0.454***	0.402***
log_Female Education	-0.072**	-0.042*
Physician density	-0.062*	-0.084**
log_Health Expenditure per capita (t-1)	-0.075	-0.049
log_ors	0.003	-0.003
log_cereal	-0.245***	-0.226***
log_urbanization	-0.115	-0.262**
Breastfeeding	0.039	0.007
year		
2000	(empty)	(empty)
2001	0.612***	0.618***
2002	0.551***	0.555***
2003	0.492***	0.498***
2004	0.444***	0.449***
2005	0.417***	0.416***
2006	0.384***	0.380***
2007	0.338***	0.331***
2008	0.308***	0.297***
2009	0.261***	0.248***
2010	0.206***	0.196***
2011	0.168***	0.159***
2012	0.135***	0.127***
2013	0.103***	0.093***
2014	0.081***	0.070***
2015	0.032**	0.027*
2016	0.001	-0.002
2017	(empty)	(empty)
Constant	8.415***	9.844***
Country	*47*	*47*
N	*795*	*795*
R2	*88%*	*88%*

Note: Sample 47 countries, 2000-2017. Standard errors in parentheses. * p<.05; ** p<.01; *** p<.001. Source: WHO/UNICEF- JMP; IHME -Global Burden of Disease Study 2019 Results; WORLD BANK - World Development Indicators.

Table 14. Diarrhea Mortality - **Random Effects** Models accounting for the effects of water access inequality. **Driscoll-Kraay standard errors**.

Variables	(9) Child mortality diarrhea	(10) Infant mortality diarrhea
Models	RE-3	RE-4
log_water access inequality	0.096***	0.067**
log_sanitation access inequality	0.066	0.060
log_GDP per capita	-0.339***	-0.328***
log_GINI	0.441***	0.394***
log_Female Education	-0.088*	-0.052*
Physician density	-0.074*	-0.094**
log_Lagged Health Expenditure per capita	-0.073	-0.047
log_ors	-0.006	-0.010
log_cereal	-0.245***	-0.227***
log_urbanization	-0.187	-0.297*
Breastfeeding	-0.003	-0.035
year		
2000	(empty)	(empty)
2001	9.662***	0.580***
2002	9.605***	0.519***
2003	9.548***	0.463***
2004	9.503***	0.416***
2005	9.479***	0.384***
2006	9.451***	0.351***
2007	9.408***	0.305***
2008	9.383***	0.273***
2009	9.339***	0.227***
2010	9.288***	0.177***
2011	9.254***	0.143***
2012	9.226***	0.114***
2013	9.199***	0.084***
2014	9.181***	0.064***
2015	9.136***	0.023**
2016	9.109***	-0.003
2017	9.110***	(empty)
Constant	0.000	10.256***
Country	*47*	*47*
N	*795*	*795*
R2/ rho	*60/98%*	*54/98%*

Note: Sample 47 countries, 2000-2017. Standard errors in parentheses. * p<.05; ** p<.01; *** p<.001. Source: WHO/UNICEF- JMP; IHME -Global Burden of Disease Study 2019 Results; WORLD BANK - World Development Indicators.

Robustness check

Table 15. Diarrhea Mortality Models (by age and gender) accounting for the effects of water access inequality. **Driscoll-Kraay standard errors**

Variables	Alternative Mortality Data U5MRD, female		Alternative Mortality Data U5MRD, male		Alternative Mortality Data Infant MD, female		Alternative Mortality Data Infant MD, male	
Models	FE-5	RE-5	FE-6	RE-6	FE-7	RE-7	FE-8	RE-8
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
log_water access inequality	0.070***	0.096***	0.065***	0.094**	0.036	0.057*	0.050***	0.073**
log_sanitation access inequality	0.034	0.047	0.068*	0.081*	0.026	0.036	0.068*	0.079*
log_GDP per capita	-0.238*	-0.262**	-0.380***	-0.398***	-0.248*	-0.261**	-0.375***	-0.382***
log_GINI	0.520***	0.505***	0.406***	0.394***	0.487***	0.477***	0.342***	0.335***
log_Female Education	-0.099**	-0.114**	-0.051*	-0.067*	-0.073**	-0.083**	-0.014	-0.026
Physician density	-0.041	-0.052	-0.079**	-0.092**	-0.053*	-0.063*	-0.109**	-0.121***
log_Health Expenditure per capita (t-1)	-0.068	-0.066	-0.080*	-0.079	-0.048	-0.046	-0.049	-0.048
log_ors	0.001	-0.006	0.004	-0.006	-0.010	-0.016	0.003	-0.005
log_cereal	-0.254***	-0.254***	-0.241***	-0.241***	-0.236***	-0.236***	-0.224***	-0.225***
log_urbanisation	-0.100	-0.184	-0.138	-0.202	-0.190*	-0.245*	-0.321**	-0.337*
Breastfeeding	0.129	0.096	-0.022	-0.075	0.056	0.025	-0.007	-0.063
year								
2000	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)	(empty)
2001	0.643***	8.742***	0.593***	10.409***	0.642***	9.782***	0.609***	11.661***
2002	0.580***	8.682***	0.534***	10.353***	0.576***	9.719***	0.548***	11.601***
2003	0.520***	8.626***	0.475***	10.297***	0.519***	9.663***	0.490***	11.544***
2004	0.470***	8.579***	0.429***	10.253***	0.468***	9.615***	0.441***	11.497***
2005	0.440***	8.553***	0.402***	10.230***	0.435***	9.584***	0.407***	11.465***
2006	0.407***	8.524***	0.371***	10.203***	0.400***	9.552***	0.371***	11.431***
2007	0.358***	8.480***	0.325***	10.161***	0.351***	9.506***	0.322***	11.384***
2008	0.329***	8.454***	0.296***	10.136***	0.317***	9.474***	0.287***	11.352***
2009	0.284***	8.413***	0.246***	10.089***	0.270***	9.430***	0.236***	11.303***
2010	0.229***	8.362***	0.191***	10.038***	0.218***	9.381***	0.183***	11.253***
2011	0.189***	8.327***	0.153***	10.005***	0.179***	9.346***	0.146***	11.220***
2012	0.155***	8.297***	0.122***	9.979***	0.146***	9.315***	0.116***	11.192***
2013	0.118***	8.265***	0.092***	9.954***	0.107***	9.281***	0.084***	11.164***
2014	0.090***	8.242***	0.074***	9.941***	0.079***	9.256***	0.065***	11.148***
2015	0.038**	8.194***	0.028*	9.898***	0.031*	9.211***	0.024*	11.108***
2016	0.004	8.163***	-0.001	9.873***	0.000	9.182***	-0.003	11.084***
2017	(empty)	8.162***	(empty)	9.876***	(empty)	9.184***	(empty)	11.088***
Constant	7.405***	0.000	9.215***	0.000	8.671***	0.000	10.747***	0.000
Country	*47*	*47*	*47*	*47*	*47*	*47*	*47*	*47*
N	*795*	*795*	*795*	*795*	*795*	*795*	*795*	*795*
R2/ rho	*87%*	*57/98%*	*88%*	*61/98%*	*88%*	*59/98%*	*87%*	*56/98%*

Note: Sample 47 countries, 2000-2017. U5MRD - child mortality diarrhea age under 5. Infant MD – infant mortality diarrhea. Standard errors in parentheses. * p<.05; ** p<.01; *** p<.001. Source: WHO/UNICEF- JMP; IHME -Global Burden of Disease Study 2019 Results; WORLD BANK - World Development Indicators.

Moreover, we found a strong evidence that water access inequality accounts for 9.6 percent of child mortality under the age of 5 caused by diarrheal disease per 1000 live births, and 6.7 percent of infant mortality caused by diarrheal disease per 1000 live births, by accounting for the major socio-economic and health care determinants of child mortality in the context of 47 low-and-middle-income countries. The key findings therefore indicate that water access inequality is a significant determinant of diarrhea mortality across age groups. This offers a new insight to the current debate of child mortality which concentrates on the role of an economic change (endorsed by GDP per capita growth), a social change (endorsed by a change in female education), and a medical technology change (endorsed by an increase in immunization coverage). In comparison to these factors, we have the following findings. In terms of both significance and a size of the effect, water inequality was stronger and bigger than female education. Although the effect size of economic growth (GDP per capita) was bigger than water access inequality, its effect was offset by the effect of income inequality across all models. Oral rehydration therapy was found insignificant. It seems to indicate that the use of treatment is not enough in many of the countries in which diarrhea mortality levels remain high.

It should be noted that the results of the fixed and random effects models with the robust Driscoll–Kraay standard errors were largely consistent with the results of the same models without Driscoll–Kraay standard errors. However, our main findings are derived from the robust random effects models as suggested by Hausman's specification test performed. When comparing the effect sizes of these results to the results of robust fixed effects models, we observed that 8 out of 11 factors showed larger effect sizes in the random effects models. In addition, 3 variables gained significance, 3 retained significance, and 3 showed no change in significance. This suggests that our preferred model, the robust random effects model, demonstrated higher efficiency compared to the fixed effects models.

Furthermore, in assessing the sensitivity of our models, robustness checks were carried out using alternative mortality data, which is gender disaggregated child and infant mortality caused by diarrhea. The findings are largely consistent with the results of the core models (Table 15). This suggests that our findings are robust.

5.4 Summary

The chapter aimed to investigate whether and extent to which water access inequality affects child diarrhea mortality from a health economics perspective, framed by Chapter 2. Findings suggest water access inequality as a key explanatory variable in explaining child diarrhea mortality in LMICs. In doing so, we addressed the role of the distribution of water access in health, which has been unclear in the literature (Besnier et al., 2021; Hoddinott, 1997; Setty et al., 2020, 2019), although the role of water is well studied. On the other hand, child mortality is understudied outcome variable (Fink et al., 2011), although child morbidity is studied widely in relation to the role of water. Moreover, the cause-specific-child mortality is rarely being studied as the literature review revealed in Chapter 2.

To this end, we constructed a variety of ten child mortality models to evaluate the likely effects of water access inequality on two child mortality outcomes: diarrheal child mortality age under 5 (i) and diarrheal infant mortality (ii). As a robustness check, the empirical tests were repeated with age and gender disaggregated diarrhea mortality datasets for both outcomes. This leads to estimating eight additional mortality models, because baseline models are no longer relevant at this stage. We combined comprehensive international datasets from three different sources to feed 17 variables in our models.

The main contribution of this chapter is manifold. *First*, we bring a new explanatory variable – water access inequality – into global child mortality debate from a health economics perspective in which we recognize the role of the distribution of water access for child survival in LMICs. The current key debate is concentrated on the role of an economic change, a social change (endorsed by a change in female education), and a medical technology change. Initially, the explanations were competing, yet the view has eventually changed. The recent studies tend to emphasize that the explanations are actually sequential, thus complementary (Jamison et al., 2016). *Second*, we integrated a new global dataset on cause-specific-child and infant mortality, in the panel. This dataset is recently commenced by The Institute for Health Metrics and

Evaluation. *Third*, we improved quality of the analysis by relying on a large *N* panel of observation rather than a small cross-sectional observation such as M.M. Hasan and Alam (2020). *Fourth,* we took two important measures in order to improve efficiency and accuracy of the panel models. We interpolated some missing variables where needed in line with important literatures previously published (Anand and Bärnighausen, 2007; Jamison et al., 2016). It, therefore, helps the panel to be more balanced and avoid from omitting important information due to a data gap. Furthermore, the fixed-effects model is extended by including time-fixed-effects (Greene, 2003) (i) and by including Driscoll-and-Kraay standard errors (Hoechle, 2007) (ii). Therefore, the models provide a robust conclusion that child mortality is significantly positively associated with water access inequality with the 99,9% confidence interval, while the result supports the same association for infant mortality outcome with the 99% confidence interval (Table 13).

Our study has also several limitations, which, in turn, suggest future research directions. First, the findings may not be useful to inform policies concerning water access inequalities caused by ethnic, racial, and geographic stratifiers. Second, a fixed-effects model does not address causality in the relationship, although it can address endogeneity at a certain extent. It, therefore, suggests a further investigation seeking causality. For this reason, I recommend using one of the several possible econometric methods, which are an instrumental variable approach and the quasi-experimental methods such as differences-in-difference and propensity score matching, if the structure of the data in hand fits the design of the selected method. Third, Rotavirus vaccine is excluded in the model due to the lack of sufficient data because it is one of the new and under administrated vaccines compared to other routine vaccines such as DPT3. This does not allow an accumulation of necessary data for a cross-country long observational study to date. On the other hand, this status of vaccine may suggest that its effect on mortality prevention maybe insignificant at the global level specially during the period between 2000-2017 due to its coverage rate and length, but not due to its efficiency. In addition, fourth, although it is not a limitation, it is worth to investigate how water access inequalities affect child mortality inequalities in future research.

Chapter 6

Do Water Access Inequalities Hinder Child Mortality Decline? A Perspective from Liberia & Zimbabwe

6.1 Introduction

To complement the results of the quantitative study in Chapter 5, this chapter aims to test whether there is an association between changes in water access inequality and changes in child diarrhea mortality by applying a comparative case study approach. In doing so, we examine all countries in our sample in order to identify the success and failure; and then compare the cases of 'success' - Liberia and 'failure' - Zimbabwe. The outcome variable is child diarrhea mortality under age five, while the explanatory variable is water access inequality index. Data on child diarrhea mortality are sourced from IHME datasets, and data on water access inequality are derived from our estimates in Chapter 4. In line with the theoretical literature, we additionally investigated several explanatory variables: economic growth and income per capita, female education, Rota-vaccine, and public health expenditure. The relevant data are sourced from World Development Indicators, Human Development Indicators, and Word Health Organization.

The analysis starts by identifying a global trend of child diarrhea mortality across 61 low-and-middle-income countries, thus assessing the progress. We then identified the patterns in child diarrhea mortality and its association with the water access inequality. Thirdly, we ask, 'Do water access inequalities hinder child mortality decline?'. To answer this question, countries are ranked based on their performance in reducing child diarrhea mortality between 2000 and 2017 (Table 16). Criteria for success and failure in child mortality reduction are also defined, providing insights for which countries succeeded and which did not. A change analysis (Figure 11) building on the global ranking for child diarrhea mortality (Table 16) and water access inequality (Table 7 in Chapter 4) provided an evidence which was compared and contrasted. Finally, an in-depth comparison of two countries—Liberia and Zimbabwe—are taken off.

6.2 Trend in child diarrhea mortality: Uneven progress across the countries

It is evident that efforts toward reducing preventable child mortality, particularly caused by diarrhea, have been progressive across 61 low-and-middle-income countries (LMICs) during the period between 2000 and 2017 (Figure 12). Despite the progress made, the absolute mortality rate remains substantial in Sub-Saharan Africa (SSA) compared to all other SDG regions (Table 15). As of 2017, SSA achieved a 64% reduction compared to 2000; however, its total rate of under 5 mortality caused by diarrhea stands at 5818.99 per 1000 live births, accounting for 88% of the total global mortality rate. In comparison to other regions, SSA's mortality rate is 19 times higher than Central & Southern Asia, 24 times greater than Northern Africa & Western Asia, and 41 times higher than Latin America & the Caribbean. Therefore, it is necessary to focus on SSA to address global under 5 mortality caused by diarrhea. The least mortality-vulnerable region was Europe & Northern America.

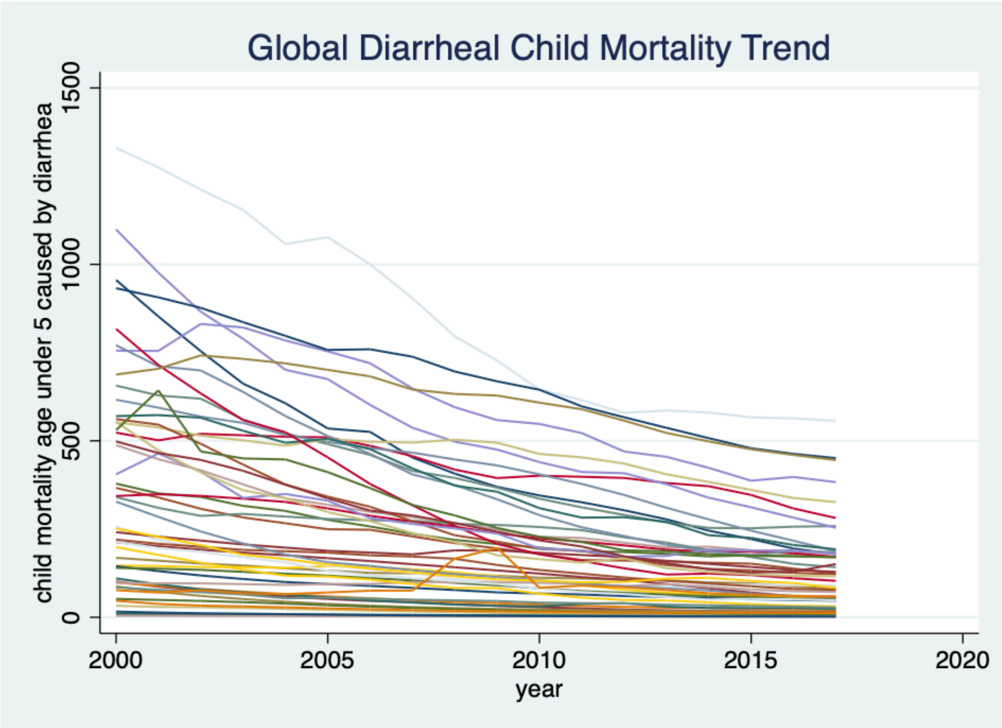
Table 16. Child Mortality under age 5 caused by Diarrhea in LMICs

SDG Region	U5MRD (per 1000)		
Year	2000	2017	Change %
Central & Southern Asia	1.160,02	300,24	-74%
Eastern & South-Eastern Asia	337,36	97,87	-71%
Europe&Northern America	13,59	3,85	-72%
Latin America & the Caribbean	591,33	140,84	-76%
Northern Africa & Western Asia	746,55	244,41	-67%
Sub-Saharan Africa	16.028,88	5.818,99	-64%

Source: Own construct. IHME mortality dataset (*n=61).* U5MRD (per 1000) denotes the rate of under-five mortality caused by diarrhea per 1000 people.

The statistics from the base year reveal that the top 5 most mortality-vulnerable countries were in Sub-Saharan Africa, including Niger (1330 per 1000 live births), Liberia (1099 per 1000 live births), Angola (956 per 1000 live births), Nigeria (932 per 1000 live births), and Rwanda (817 per 1000 live births). On the other hand, the top 5 least mortality-vulnerable countries were in Europe & Northern America, including Montenegro (1 per 1000 live births), Bosnia and Herzegovina (2 per 1000 live births), Albania (3 per 1000 live births), Ukraine (3 per 1000 live births), and Belarus (4 per 1000 live births).

Figure 12. Trend of Child Mortality caused by diarrhea age under 5 across low-and-middle-income countries 2000-2017



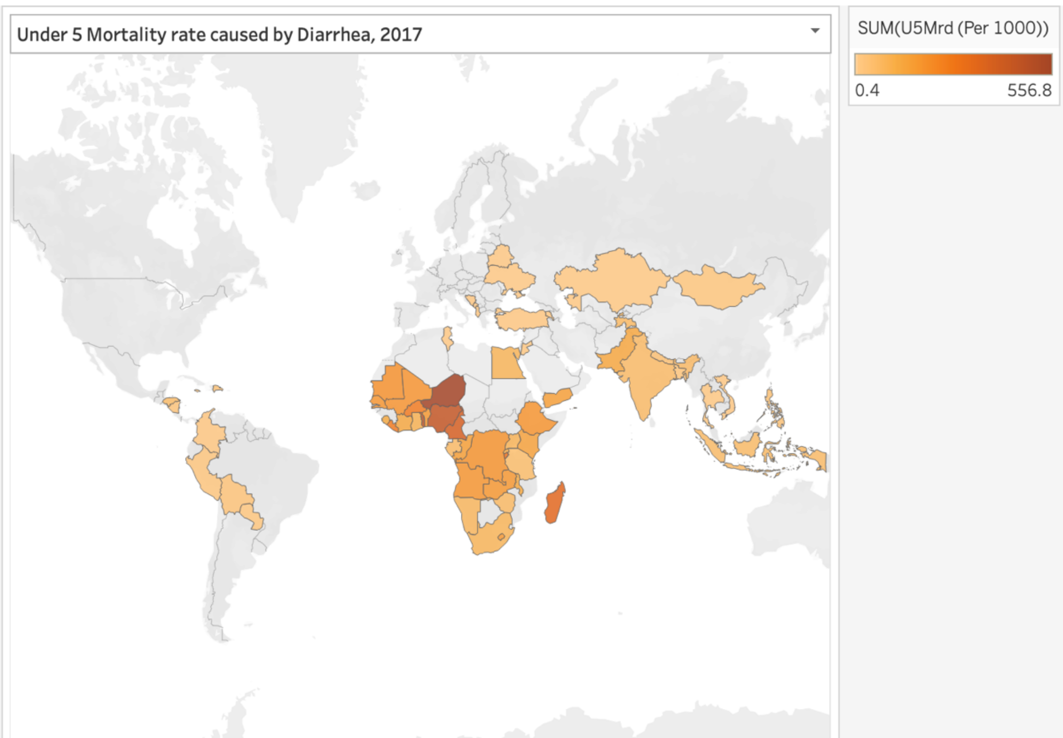
Source: Own construction. Trend in Child diarrhea mortality age under 5 across 61 low-and-middle-income countries, 2000-2017, estimated based on the IHME datasets.

6.3 Patterns in child diarrhea mortality and its relationship with water access inequality

As of 2017, Niger and Nigeria continued to lead as the *most* mortality-vulnerable countries with mortality rates of 557 and 451 per 1000 live births, respectively. On the other hand, Rwanda, Liberia, and Angola succeeded in flattening their risk. However, Togo, Cameroon, and Madagascar have been added to the list with rates of 445, 383, and 327 per 1000 live births, respectively. Regarding the *least* mortality-vulnerable countries, the same five countries remained on the list with rates ranging between 0.4 to 1.4 per 1000 live births. These numbers are graphically illustrated by the Child mortality map that simultaneously provides an overview of the countries where child mortality under 5 caused by diarrhea is most and least intense as of 2017 (Figure 13).

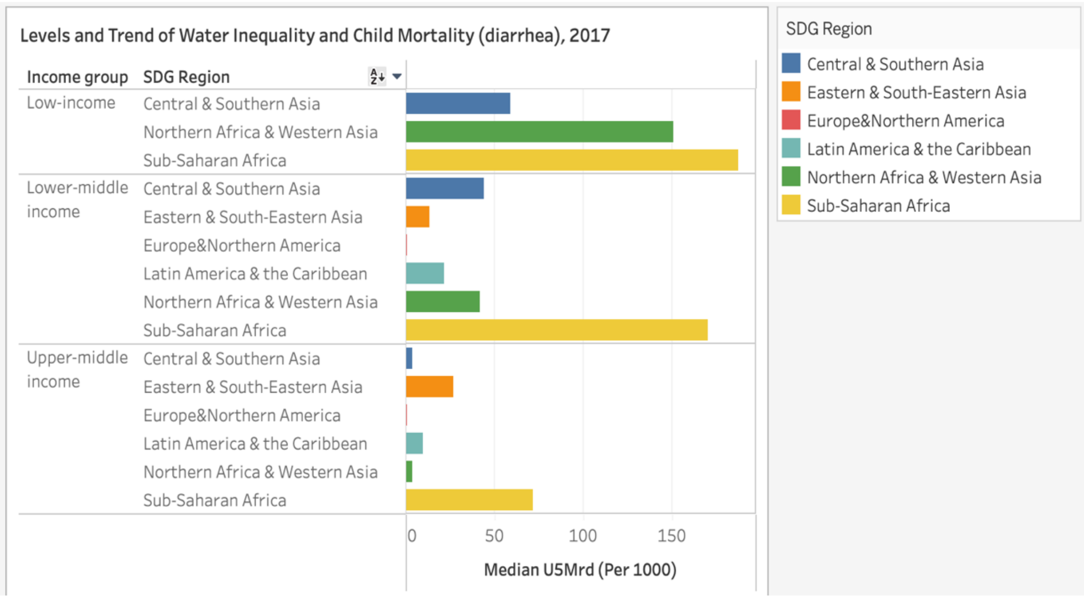
Furthermore, we are interested in mortality rates according to country's income classification. Figure 14 reveals two patterns. First, the highest rate of child mortality falls under the low-income group, followed by the lower-middle-income, while the lowest rate of child mortality corresponds to the upper-middle-income category. This seems in line with the child mortality hypothesis of economic growth (Filmer and Pritchett, 1999, 1997). Second, we disaggregated the countries by the corresponding regions within the income groups. This reveals that income does not always explain the level of mortality rate. For example, countries in Sub-Saharan Africa in the category of upper-middle income have a much higher rate than those in all regions of the lower-middle-income group, and higher than the rate of Central & Southern Asia in the low-income group. This suggests that other determinants, together with economic growth, may jointly come into play in explaining child mortality. It is, once again, consistent with the relevant literature that we discussed in Chapter 2 and leads to a suspect that water access inequality maybe an important determinant.

Figure 13. Child mortality map (age under 5, caused by diarrhea) LMICs, 2017



Note: Own construct. IHME mortality dataset (*n=61*). U5MRD (per 1000) denotes the rate of under-five mortality caused by diarrhea per 1000 people.

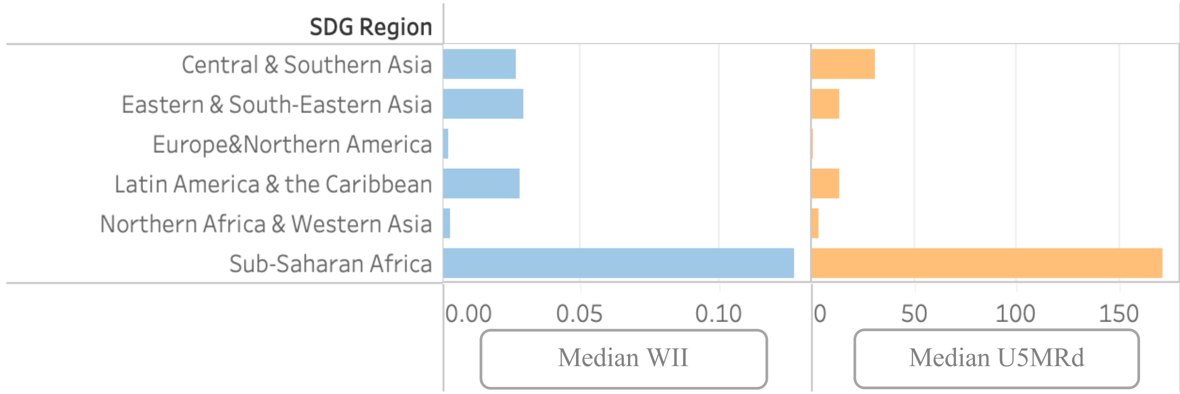
Figure 14. Child mortality (age under 5, caused by diarrhea) in LMICs as of 2017: disaggregated by income groups and SDG regions



Note: Own construct, IHME dataset (*n=61*). Income groups are based on the World Bank's classification.

We also identify the signs of association between water access inequality and child diarrhea mortality. Water access inequality index, as constructed in Chapter 4, is used to build median WII to illustrate regional patterns alongside median U5MRd across SDG regions (Figure 15). It reveals that a higher rate of inequality corresponds to a higher rate of mortality, while lower inequality is parallel to lower rate of mortality. In line with the previous analyses, Sub-Saharan Africa is the worst performer in terms of both indicators, followed by Asia and Latin America.

Figure 15. SDG Regions: Water Access Inequality and Diarrheal Child Mortality Age under 5



Source: Own construct. IHME dataset (*n=61*). WII – water access inequality index; U5MRd – rate of child mortality age under 5 caused by diarrhea, per 1000 live births.

The relationship under scrutiny is not only described by SDG regions, but also described by income levels of the countries. It is based on the World Bank's country classification[16]. Data in our sample does not include high income countries. Therefore, as shown in Figure 14, low-income, lower-income, and upper-middle income countries are covered. The analysis suggests four patterns.

First, low and lower-income countries exhibit a higher level of inequality in water access and a higher level of child diarrhea mortality.

Second, most lower income countries perform quite well in terms of both inequality and mortality.

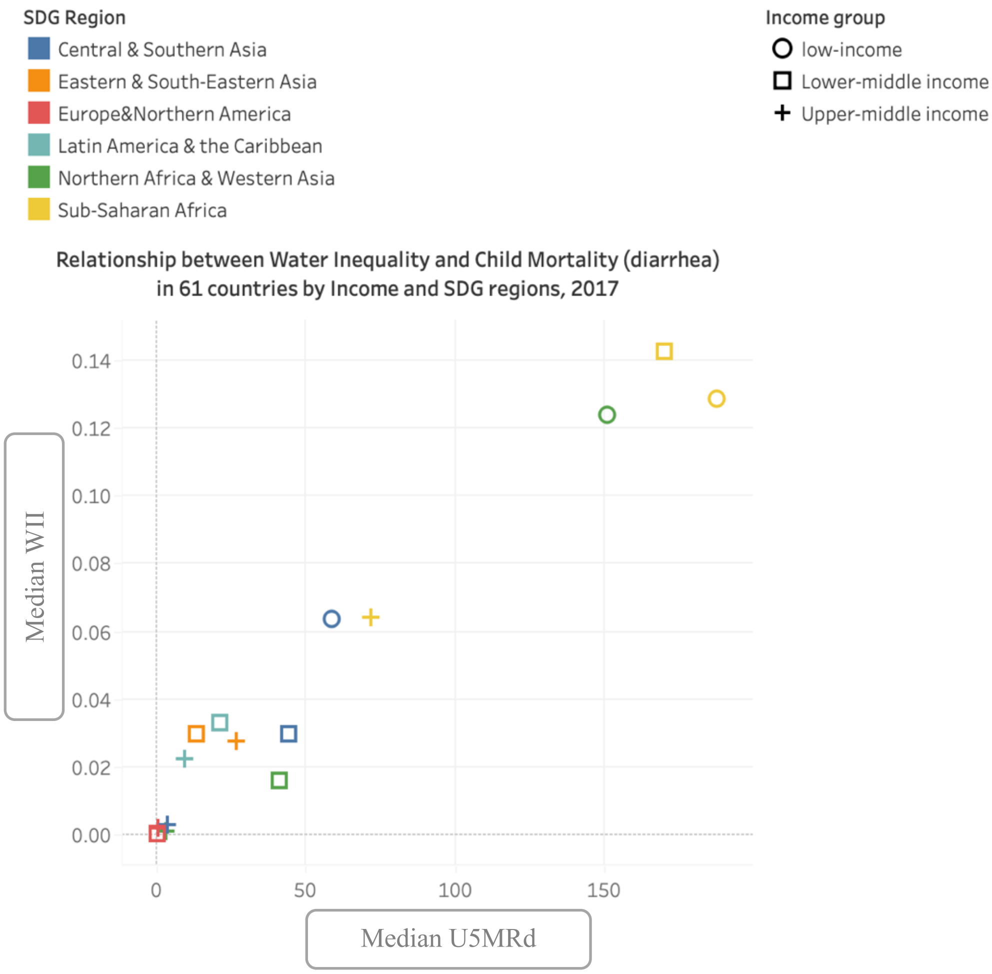
Third, there are regional differences are observed in the same income levels. For low-income category, Central Asian countries perform much better than countries of Sub-Saharan Africa and Northern Africa & Western Asia. For lower-middle income category, countries in all other regions perform significantly better than the countries in Sub-Saharan Africa. Their performances fall at the spectrum where the performances of upper-middle income countries

[16] Methodology details: World Bank Group country classifications by income level for FY24 https://blogs.worldbank.org/opendata/new-world-bank-group-country-classifications-income-level-fy24

fall. Yet, the best performance, parallel to both inequality and mortality, is found for the countries from Europe & North America. In terms of upper-middle income countries, best performers are two regions: Central & Southern Asia and Europe & North America. The worst performer is again Sub-Saharan Africa. The rest is in the middle.

Four, all SDG regions in the pattern revealed by Figure 16 jointly show that there is an association between water access inequality (axis-y) and child diarrhea mortality (axis-x). These findings, thereby, support for the hypothesized relationship tested in Chapter 5.

Figure 16. Relationship between Water Inequality and Child Mortality (diarrhea) in Low-and-Middle Income countries by Income and SDG regions, 2017



Note: Own construct. Y axis – a median rate of Water access inequality index (WII). X axis - a median rate of Child mortality under 5 caused by diarrhea per 1000 live births. Countries are grouped by World Bank's income groups and SDG regions. Data: IHME data & Own estimates of WII based on the JMP data of WHO/UNICEF (*n=61).*

6.4 Do water access inequalities hinder child mortality decline?

Global trends in water access inequality (Figure 7 in Chapter 4) and global trends in child diarrhea mortality (Figure 12) are both declining, yet the declines have been disproportional across the countries. It is to note that although majority of the countries observe declining trend in WII, there is few countries show an opposite trend. Taking these trends in mind, we are interested in exploring whether changes in water access inequality are associated with changes in child diarrhea mortality (ii), which leads to Hypothesis-2.

> **H-2:** *Changes in water access inequality (WII)* are significantly associated with *changes in child diarrhea mortality (CDM)*

To understand whether and how success/failure in child mortality reduction is associated with change in water access inequality, given that both decrease and increase happened in WII we generated two **sub-hypotheses**:

H-2.1: Decrease WII – Success CDM

H-2.2: Increase WII – Failure CDM

Data suggests that the following additional hypotheses, which are related to H-2 but more nuanced.

H-2.3: Absence of progress WII - Success CDM, if
the absence of change in WII is due to the presence of a high initial coverage of water

H-2.4: Absence of progress WII - Failure CDM, if
the absence of progress in WII is due to the absence of improvement towards full coverage of water

Findings in brief:

Comparative case study analysis with its two-stages process found largely confirmatory results for all sub-hypotheses (H-2.1, H-2.2, H-2.3) except for H-2.4. Building on the results, we assume that the reason for the result from testing H-2.4 is related to outcome variable. We found evidence that the effects of changes in water coverage for rich may camouflage the effects of changes in water coverage for poor. This suggests inequality-inequality analysis, in other words, suggesting future research using mortality inequality data. This finding, however, does not contradict our finding of Chapter 5. Moreover, it is maybe useful to consider quasi-experimental like design given that there are some countries did not make a change in WII because their coverage of water is already very high. It may allow another research comparing countries with inequal distribution of water access and countries with equal distribution with water access. In summary, considering findings from both stage-1 and stage-2 analyses, the result is that water access inequality, on average, may hinder progress towards reducing child diarrhea mortality. This is in line with our finding of Chapter 5.

Table 17. Summary of the results of a comparative case study: Stage-1

No	Hypotheses	Analysis	Performance in CDM	Performance in WII	Implication
H-2.1	Decrease WII - Success CDM	Accept	**Success:** Kazakhstan,	Decrease in WII	
H-2.2	Increase WII - Failure CDM	Accept	**Failure:** Zimbabwe	Increase in WII	
H-2.3	Absence of progress WII - **Success CDM**, if the absence of change in WII is due to the presence of a high initial coverage of water	Accept	Outlier analysis **Success**: Turkey, Bangladesh	the absence of improvement towards full coverage of water _due to No change in WII	a quasi-experimental like design in which two groups are composed
H-2.4	Absence of progress WII - **Failure CDM**, if the absence of progress in WII is due to the absence of improvement towards full coverage of water	Accept	**Failure:** Jordan, South Africa, Lesotho, Jamaica, and Zimbabwe	the absence of improvement towards full coverage of water _due to Increase in WII	

		Fail to reject null hypothesis (thus, do not accept alternative hypothesis)	Outlier analysis: Success: Rwanda, Angola	the absence of improvement towards full coverage of water _due to Increase in WII Rwanda: increase in WII, due to increase in coverage for rich only Angola: increase in WII, due to increase in coverage for rich, decrease in coverage for poor	Rich benefits from increase in water access, while poor does not if poor's access does not change or improve. -Either case, it increases WII. -health gain of the rich may offset health loss of the poor, which in turn appear as a net health gain for the general population. -WII is bad for health of poor. -to unmask this, inequality (WII)-inequality (CDM) analysis should be conducted in the future.

Note. Own construct based on the results of Stage-1 analysis.

In doing so, we ranked the countries by their achievements in terms of reducing child diarrhea mortality under age 5. The international ranking yields a 24-95% decline in child diarrhea mortality across all countries in our sample between 2000 and 2017 (Table 17). We then defined success and failure in the progress toward averting child diarrhea mortality to allow a comparative analysis. We define '*success*' as a mortality decline that occurred at a rate *higher* than the median rate (68%) of mortality decline. On the other hand, '*failure*' is defined as a mortality decline that occurred at a rate *lower* than the median rate (68%). There is more than one pair in the sample, thus a certain criterion is applied in the case selection. Moreover, the comparative study goes through 2 interconnected steps: first, qualitatively examining all low-and-middle-income countries in our sample to see whether hypothesis-2 holds and selecting the cases for comparison; second, investigating the selected cases of success and failure to test the same hypothesis through an in-depth analysis.

As the most successful case, we observe the levels of child mortality by diarrhea decreased across all countries in our sample at different rates Kazakhstan leads the LMICs in terms of the relative decline of child diarrhea mortality by achieving a 95% reduction as of 2017 compared to the base-year value. On the contrary, Zimbabwe touches the bottom line with a performance equivalent to only a 24% reduction within the same period, showcasing a failure.

Let's now have a look at the changes in the water access inequality index[17] (WII) for the same countries within the same period. Kazakhstan decreased the WII by - 83%, while Zimbabwe increased the WII by 5% (Table 7, Chapter 4). Based on these results, it is apparent that Kazakhstan's high performance in the reduction of child diarrhea mortality coincides with a significant decline in water access inequality in the same period. Whereas Zimbabwe's poor performance coincides with an increase in water access inequality. The findings support our hypothesis -2, which means, logically, supports hypothesis -1. The findings further suggest that water access inequalities may hinder success in reducing child mortality.

Moreover, we further observe that most countries, 52 out of 61, decreased child mortality in line with water access inequality decline (Figure 17: Left-hand side). It means that we observe the hypothesized relationship qualitatively for 85% of the countries in our sample.

At the same time, we have also identified several outliers: 9 out of 61 (Figure 17: Right-hand side). These nine countries managed to reduce child diarrhea mortality at a certain level, despite an absence of progress in water access inequality reduction. Among them, two countries experienced 'no change', and seven countries experienced 'an increase' in terms of water access inequality. This deserves attention.

Table 18. International Ranking: Diarrheal Child Mortality Reduction as of 2017

Country	Rank 2017	U5MRD (per 1000) in 2017	U5MRD (per 1000) in 2000	Absolute change	Relative change %	Income group	SDG Region
Kazakhstan	1	2	44	- 42	-95%	Upper-middle	CSA
Armenia	2	3	41	- 38	-92%	Upper-middle	NAWA
Belarus	3	0	4	- 4	-90%	Upper-middle	ENA
Rwanda	4	103	817	- 714	-87%	Low	SSA
Viet Nam	5	2	16	- 14	-87%	Lower-middle	ESEA
Bangladesh	6	16	101	- 85	-84%	Lower-middle	CSA
Mongolia	7	14	87	- 73	-84%	Lower-middle	ESEA

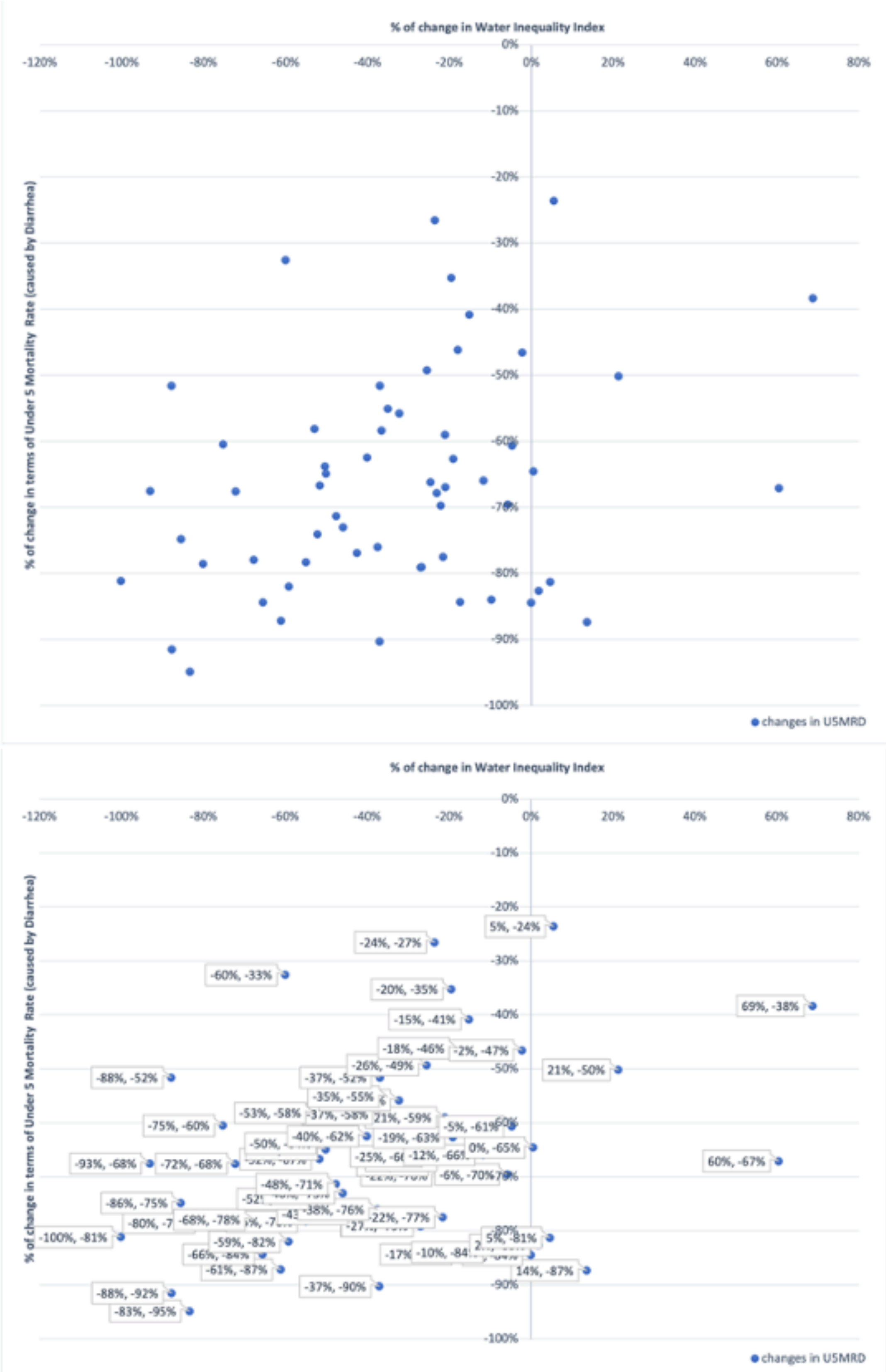
[17] WII is estimated and International Ranking is provided in Chapter 4, Table 6. To allow analysis alongside child mortality values, we used Table 6 in this chapter again, without listing it here.

Nepal	8	31	199	-	168	-84%	Lower-middle	CSA
Nicaragua	9	16	100	-	84	-84%	Lower-middle	LAC
Turkey	10	4	24	-	20	-83%	Upper-middle	NAWA
Maldives	11	6	33	-	27	-82%	Upper-middle	CSA
Tajikistan	12	59	328	-	269	-82%	Low	CSA
Angola	13	179	956	-	777	-81%	Lower-middle	SSA
Paraguay	14	10	52	-	42	-81%	Upper-middle	LAC
Colombia	15	7	33	-	26	-79%	Upper-middle	LAC
Sierra Leone	16	116	554	-	438	-79%	Low	SSA
Dominican Republic	17	24	110	-	86	-79%	Upper-middle	LAC
Malawi	18	122	562	-	440	-78%	Low	SSA
Bolivia (Plurinational State of)	19	22	98	-	76	-78%	Lower-middle	LAC
United Republic of Tanzania	20	48	214	-	166	-77%	Lower-middle	SSA
Liberia	21	254	1.099	-	845	-77%	Low	SSA
Mali	22	185	771	-	586	-76%	Low	SSA
Ukraine	23	1	3	-	2	-75%	Lower-middle	ENA
Peru	24	12	47	-	35	-74%	Upper-middle	LAC
India	25	57	213	-	156	-73%	Lower-middle	CSA
Congo	26	152	529	-	377	-71%	Lower-middle	SSA
Yemen	27	151	498	-	347	-70%	Low	NAWA
Democratic Republic of the Congo	28	188	617	-	429	-70%	Low	SSA
Zambia	29	170	530	-	360	-68%	Lower-middle	SSA
Honduras	30	47	145	-	98	-68%	Lower-middle	LAC
Albania	31	1	3	-	2	-68%	Upper-middle	ENA
Jordan	32	3	9	-	6	-67%	Upper-middle	NAWA
Uganda	33	83	252	-	169	-67%	Low	SSA
Philippines	34	28	84	-	56	-67%	Lower-middle	ESEA
Mauritania	35	193	570	-	377	-66%	Lower-middle	SSA
Côte d'Ivoire	36	125	366	-	241	-66%	Lower-middle	SSA
Ghana	37	90	257	-	167	-65%	Lower-middle	SSA
South Africa	38	78	220	-	142	-65%	Upper-middle	SSA
Indonesia	39	51	140	-	89	-64%	Upper-middle	ESEA
Ethiopia	40	182	488	-	306	-63%	Low	SSA

Gabon	41	55	147	-	92	-62%	Upper-middle	SSA
Montenegro	42	0	1	-	1	-62%	Upper-middle	ENA
Burkina Faso	43	258	657	-	399	-61%	Low	SSA
Thailand	44	4	9	-	5	-60%	Upper-middle	ESEA
Tunisia	45	2	4	-	2	-59%	Lower-middle	NAWA
Kenya	46	142	341	-	199	-58%	Lower-middle	SSA
Niger	47	557	1.330	-	773	-58%	Low	SSA
Senegal	48	179	405	-	226	-56%	Lower-middle	SSA
Benin	49	170	379	-	209	-55%	Lower-middle	SSA
Nigeria	50	451	932	-	481	-52%	Lower-middle	SSA
Egypt	51	81	168	-	87	-52%	Lower-middle	NAWA
Lesotho	52	171	344	-	173	-50%	Lower-middle	SSA
Cameroon	53	383	755	-	372	-49%	Lower-middle	SSA
Pakistan	54	129	241	-	112	-47%	Lower-middle	CSA
Burundi	55	281	523	-	242	-46%	Low	SSA
Madagascar	56	327	552	-	225	-41%	Low	SSA
Jamaica	57	4	6	-	2	-38%	Upper-middle	LAC
Togo	58	445	688	-	243	-35%	Low	SSA
Bosnia and Herzegovina	59	1	2	-	1	-33%	Upper-middle	ENA
Namibia	60	72	98	-	26	-27%	Upper-middle	SSA
Zimbabwe	61	59	77	-	18	-24%	Lower-middle	SSA

Source: Own construct based on the reduction of the rate of under 5 Child Mortality caused by Diarrhea between 2000 and 2017. **Data:** IHME (*n=61*). **Result:** The countries are ranked starting from the most successful to least successful in terms of mortality reduction. Abbreviations reflect the following SDG regions:
LAC - Latin America & the Caribbean; ENA – Europe & Northern America
NAWA - Northern Africa & Western Asia; CSA - Central & Southern Asia
ESEA - Eastern & South-Eastern Asia; SSA - Sub-Saharan Africa

Figure 17. Changes in child mortality reduction relative to Changes in water inequality index as of 2017



Note: Own construct. Changes in under five mortality caused by diarrhea (rate per 1000 live births) and changes in water access inequality. Data: IHME datasets & Own estimates based on JMP datasets (*n=61).*

When taking a closer look at the *outliers,* five countries lacked progress in water access inequality and indeed performed under the global average (-68%) in terms of mortality reduction. In particular, Jordan, South Africa, Lesotho, Jamaica, and Zimbabwe performed respectively at -67%, -65%, -50%, -38%, and -24% (Table 18). This means that although mortality decline happened in these countries, their performances were less successful. According to our definition of failure[18], these countries failed to reach the global average of child diarrhea mortality decline. One common theme that emerged from the cases of failure was "an absence of progress in water access inequality" within the same period. In particular, their performance in reducing water access inequality was 60%, 0%, 21%, 69%, 5% (Table 7 in Chapter 4). Therefore, once more, the countries failed to achieve the global average in averting child diarrhea mortality coincides with poor progress in equalizing the distribution of adequate water access. Again, this finding supports hypothesis - 2, and is in line with the findings our Chapter 5.

The outliers: Taking closer look at Bangladesh, Turkey, Rwanda, and Angola

On the contrary, there is a very few countries, in which neither an increase nor an absence of change in progress towards water access equality stopped mortality reduction (Figure 17, Right-hand side). In particular, Bangladesh, Turkey, Rwanda, and Angola managed to reduce child mortality caused by diarrhea respectively by -84%, -83%, -87% and -81%. Based on these face values, one may claim that this contradicts hypothesis - 2. Having a closer look at the disaggregated inequality data of these countries, such as Bangladesh and Turkey, reveals that countries with a high initial coverage does not have big inequalities (Figure 18). No change means either the absence of progress or the presence of equality.

Bangladesh and Turkey nearly fall under the former category. In the presence of (near) equality, it does not hinder child mortality decline, instead, it supports the mortality reduction

[18] We defined a case as a 'failure' if the performance for mortality decline of country-X is under the global average (68%).

given that the equal distribution of water access is negatively correlated with child mortality diarrhea, as proposed by Chapter 5. In other words, equal distribution of water access is expected to prevent from diarrheal infection, thus expected to lower child mortality. Which means,

> Absence of progress in WII is associated with Success in CDM, if the absence of change in WII is due to the presence of a high initial coverage of water **(H-2.3).**

On the other hand, it does not really contradict our hypothesized relationship (H-1**).** Instead, it further suggests considering a design like quasi-experimental analysis, which is composed by two groups. Group -1 includes all countries that has changes in WII, whereas group-2 includes the countries that have no change in WII. Then compare how these groups behave controlling all other relevant factors.

As far as H-2.3 is concerned, we also hypothesize the opposite relationship, assuming that it might be relevant to countries that either deteriorated or had no progress made in terms of water inequality. That is,

> Absence of progress in WII is associated with Failure in CDM, if the absence of progress in WII is due to the absence of improvement towards full coverage of water **(H-2.4).**

When taking a look at Angola and Rwanda, they achieved success in child mortality reduction, while increasing water access inequality. It fails to reject the alternative hypothesis of H-2.4. Therefore, we cannot accept this hypothesis. This warrants further investigation below.

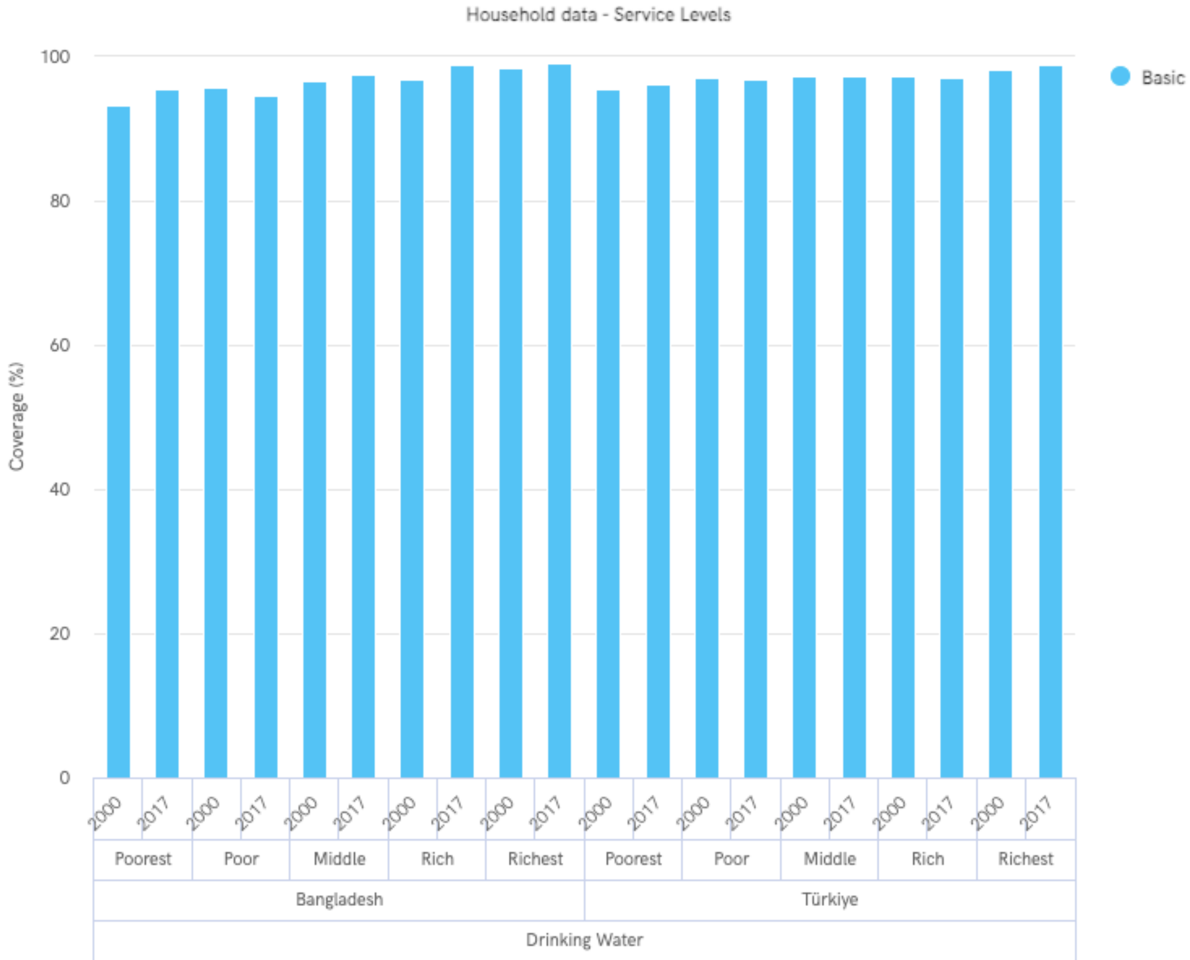
The patterns of Angola and Rwanda show how basic water access was disproportionally changed between five wealth quintiles. Water access inequalities measured by WII, increased, on average, by 5% in Angola and by 13,6% in Rwanda (Table 7 in Chapter 4). When taking a closer look at these countries in Figure 19 most increases in water coverage are attributable to rich and richest groups rather than poor and poorest groups. Angola’s water coverage decreased for the groups – poor and poorest, while it increased for the rest. Similarly, Rwanda’s water coverage slightly decreased for the poorest, while increased for the rest. These findings suggest that:

Theoretically, if increase in water inequality happened due to increase in water coverage for the rich and decrease in water coverage for the poor, the rich gains health, while the poor loses health. In this case, health gain of the rich may offset health loss of the poor, which in turn appear as a net health gain for the general population. Because of this, water inequality effect can be camouflaged when testing on the total mortality data. It further suggests that inequality-inequality analysis (inequality in water access – inequality in child mortality).

Nevertheless, health of the poor does not benefit from an increase in total water coverage, if water programs are untargeted.

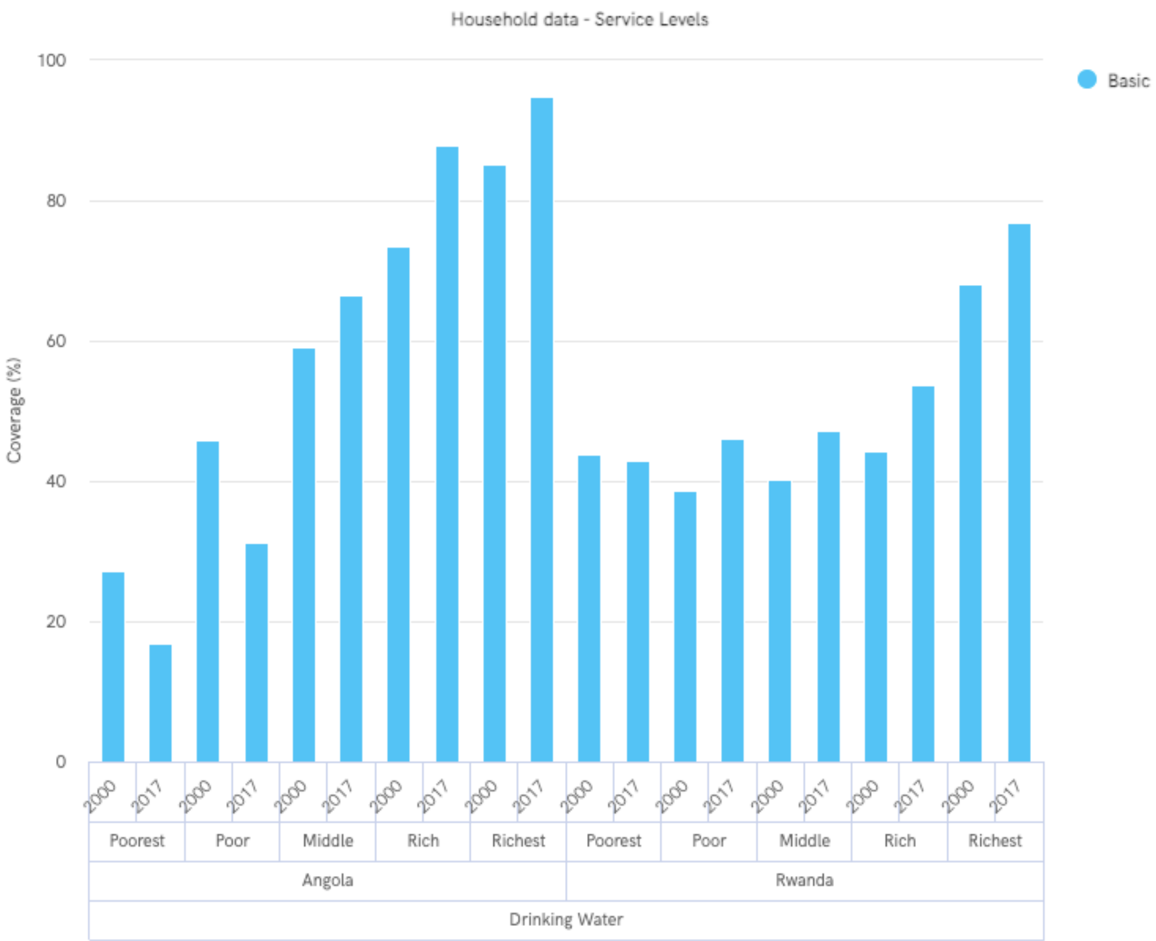
Both of these findings demonstrate the importance of the distribution of water access in reducing child diarrhea mortality. The results of the stage-1 are summarized in Table 17.

Figure 18. Change in water coverage – disaggregated by wealth quintiles – between 2000 and 2017: Bangladesh, Turkey



Note: The figure is generated by the JMP's web tool https://washdata.org/; using household data on inequality in basic water coverage (by wealth quintile). Countries: Bangladesh and Turkey. Year: 2000 and 2017. This figure shows how our estimated water access inequality index (WII) is disaggregated to wealth quintiles by each country. Wealth quintiles: Poorest, Poor, Middle, Rich, Richest.

Figure 19. Change in water coverage – disaggregated by wealth quintiles – between 2000 and 2017: Angola and Rwanda.



Note: The figure is generated by the JMP's web tool https://washdata.org/; using household data on inequality in basic water coverage (by wealth quintile). Countries: Angola and Rwanda. Year: 2000 and 2017. This figure shows how our estimated water access inequality index (WII) is disaggregated to wealth quintiles by each country. Wealth quintiles: Poorest, Poor, Middle, Rich, Richest.

The cases selected: Liberia & Zimbabwe

The several issues were considered in selecting the cases in the comparative analysis. First, the aim is to see whether change in water access inequality really explains success or failure of the efforts made for reducing child mortality. Keeping this in mind, second, we selected countries from the same region assuming that the underlying contextual factors are not too different, if not the same. For these reasons, Liberia and Zimbabwe were chosen in the analysis to represent the most and least successful countries within SSA to see whether water access inequality was a plausible reason of explaining the differences in their child mortality achievements.

Table 19. Summary of the findings: Liberia, Zimbabwe

Health achievements	Country (change in WII; change in CMD)
Success	Liberia (-43%; -77%)
Failure	Zimbabwe (+5%; -24%)

6.5 Water access inequality as a determinant of child diarrhea mortality: the cases of Liberia and Zimbabwe

6.5.1 Changes in water access inequality

The changes in water access inequality, measured by water access inequality index, in Liberia and Zimbabwe between 2000 and 2017 was -43% in Liberia and +5 % in Zimbabwe. Which means Liberia closed nearly a half of water access gap between the rich and the poor, while Zimbabwe actually increased this gap. Consequently, Liberia successfully dropped its child diarrhea mortality rates by -77%. Whilst Zimbabwe achieved only -24% reduction (Table 19). With these results, Liberia represents success, while Zimbabwe represents failure in progress towards achieving zero child mortality due to preventable disease such as diarrhea.

We further looked into the details by looking at the wealth quintiles of water access in the respective countries. Figure 20 shows how changes in water coverage happened in the wealth quintiles for Liberia. It reveals a pattern, which is quite positive and progressive. Increases in coverage of water access were proportional across all wealth quintiles, unlike Zimbabwe. Contrary to Liberia's progress, the coverage of water access increased only for the better off groups: rich and richest, while it decreased for the most vulnerable groups: poor and poorest, and nearly did not change for the middle class in Zimbabwe (Figure 21). These results suggest that *positive progress in water access inequality* coincides with *success in mortality decline* through the case of Liberia, whereas *negative progress in water access inequality* coincides with *failure in mortality decline* in the case of Zimbabwe. Based on this finding, our hypotheses (H-2.1, and H-2.2) are accepted, once more (Table 20). We, therefore, claim that progress in water access inequality matters for child mortality reduction.

The results of Liberia and Zimbabwe also mirror two issues. First, the changes in inequality and mortality of the same country are disproportional. Second, when an increase in water access inequality occurred, child mortality reduction was still possible, although at a much lower rate (such as nearly three times lower than the global average). This indicates that increase and a presence of water access inequality may hinder child mortality decline given that there are other key variables which also determine child diarrhea mortality.

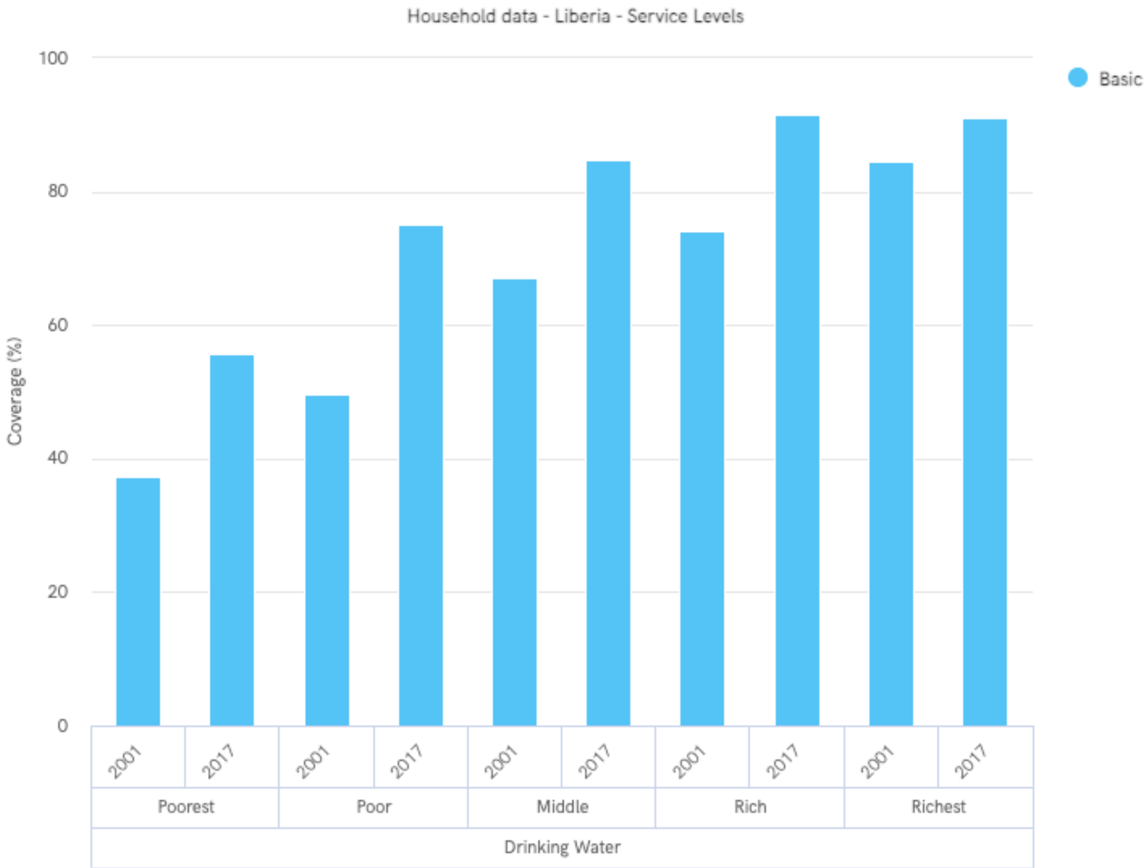
This finding matches a theoretically valid view. Health economics research acknowledges that more than one factor come into play in determining child mortality outcomes as underpinned in Chapter 2. For this reason, we want to see how other "key" child mortality determinants are changed while dropping child mortality decline. In this section, four key determinants are investigated in-depth for Liberia and Zimbabwe: Economic growth, female education, vaccination, and health expenditure. Because economic change, social change, and medical technology change[19] (vaccination) are the key building blocks in the debate of child mortality decline (Jamison et al., 2016). We also include health care expenditure as a proxy to health care variable because it is often debated alongside economic growth variable (Filmer and Pritchett, 1997).

Table 20. Summary of the results of a comparative case study: Stage-2

N	Hypotheses-2	Analysis	Performance in CDM	Performance in WII
H-2.1	Decrease WII - Success CDM	Accept	Success: Liberia	<u>Decrease in WII</u>
H-2.2	Increase WII - Failure CDM	Accept	Failure: Zimbabwe	<u>Increase in WII</u>

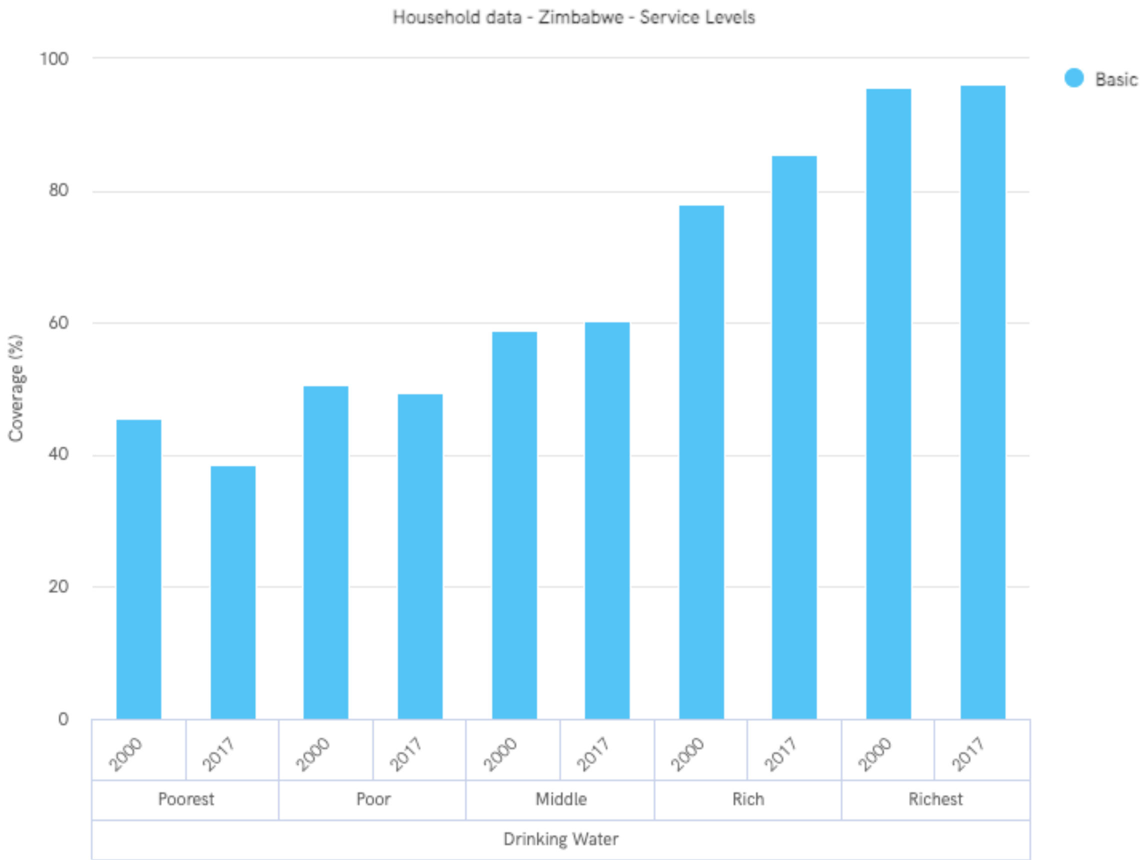
[19] Vaccination variable is included in a qualitative analysis although it does not provide sufficient information. Liberia has records for only 2016 and 2017 and Zimbabwe's record shows 2014-2017. This is the reason we excluded this variable in the quantitative model in Chapter 5.

Figure 20. Change in water coverage – disaggregated by wealth quintiles – between 2000 and 2017: Liberia



Note: The figure is generated by the JMP's web tool ; using household data on inequality in basic water coverage (by wealth quintile). Year: 2001 and 2017. This figure shows how our estimated water access inequality index (WII) is disaggregated to wealth quintiles by each country. Wealth quintiles: Poorest, Poor, Middle, Rich, Richest.

Figure 21. Change in water coverage – disaggregated by wealth quintiles – between 2000 and 2017: Zimbabwe

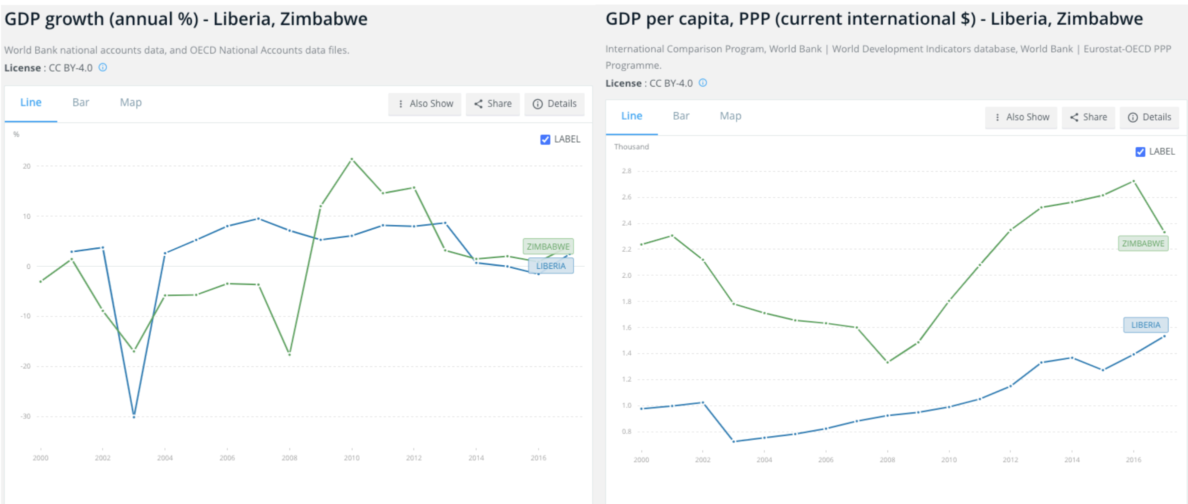


Note: The figure is generated by the JMP's web tool https://washdata.org/; using household data on inequality in basic water coverage (by wealth quintile). Year: 2000 and 2017. This figure shows how our estimated water access inequality index (WII) is disaggregated to wealth quintiles by each country. Wealth quintiles: Poorest, Poor, Middle, Rich, Richest.

6.5.2 Economic change: GDP growth & GDP per capita

Figure 22 shows that Zimbabwe and Liberia, both experienced economic growth and downturn at some point between 2000 and 2017, but Zimbabwe seems endured much more severe economic downturns. Although both countries exhibited some degree of instability, Zimbabwe's case was extreme. For example, its economic growth fluctuated between -17.7% and 21.5%. Despite facing numerous crises, Zimbabwe's GDP per capita remained the highest compared to Liberia consistently above $2200 by the end of 2017. Liberia's income per capita gradually caught up with Zimbabwe's, approaching nearly $2000 due to relatively stable increases. As of 2017, Although Liberia reached $1533, it remains in the low-income group, while Zimbabwe is in the lower-middle-income group[20]. Despite Liberia having a much lower GDP per capita than Zimbabwe, it successfully managed to reduce the child mortality rate, while Zimbabwe's performance was the lowest compared to all 61 countries in our sample. This pattern points out that a higher GDP per capita does not really respond to success/failure in country's health achievement.

Figure 22. Economic growth and GDP per capita –Liberia, Zimbabwe (2000-2017)



Source: (World Bank. World Development Indicators (WDI), 2021b). License: CC BY-4.0
https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2017&locations=LR-ZW&start=2000
https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?end=2017&locations=LR-ZW&start=2000

[20] Countries are classified by their income levels according to World Bank and this classification is embedded in both mortality and water datasets.

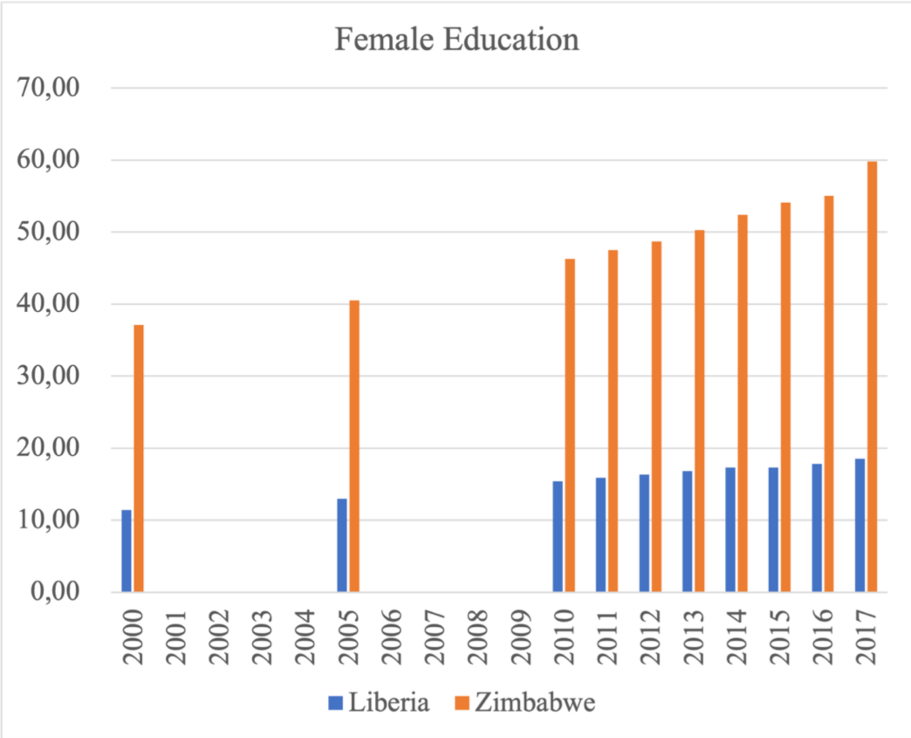
Key message 6.5.2:

Despite having lower levels of GDP per capita and GDP growth, Liberia succeeded in reducing their child mortality rates at a much higher pace than Zimbabwe. It means Liberia's success is not explained by economic change in comparison to Zimbabwe, aka., it does not suggest any reason to weaken the likely effect of changes in water access inequality on changes in child diarrhea mortality.

6.5.3 Social change: Female education

Female education is known as an important determinant of child mortality and its decline (Caldwell, 1994, 1986). As a proxy of this variable, we took a closer look at the data on the female population with at least some secondary education for the countries under scrutiny. The data indicates an improvement in the female education status across countries (Figure 23). The relative change was nearly same for both countries: Liberia improved female education by 62% while Zimbabwe improved it by 61%. Improvement translates into the expected relationship – the better the female education, the greater the mortality reduction. When it comes to the absolute value, the highest performer was Zimbabwe, with a percentage of the female population having some secondary education reaching 60% by 2017, compared to 37% in 2000. On the other hand, Liberia performed much poorer in this regard. The change was much lower, female population having some secondary education touches 18.5 percent as of 2017 departing from 11.4 % in 2000. These results indeed contrary to the assumption that better education – better health for these countries. However, if we look at the absolute value of child diarrhea mortality in both countries, Zimbabwe's mortality rate initially was much lower than Liberia's rate of mortality. This is in line with the theoretical explanation.

Figure 23. Population with at least some secondary education, female (% ages 25 and older)



Source: UNESCO Institute for Statistics (2020) and Barro and Lee (2018).

Key message 6.5.3:

Female education matter for child mortality, yet the changes in education variable did not really show any significant impact to the cases of two countries. This finding does not indicate any hint on weakening the likely effect of changes in water access inequality on changes in child diarrhea mortality.

6.5.4 Medical technology change: Rota-vaccine

Based on the vaccination data obtained from WHO, Liberia started administering Rota-vaccine in the years of 2016 and 2017. The coverage increased from 48 unit to 71 unit. The same intervention was started in Zimbabwe, slightly earlier than Liberia, in 2014 (Table 19). Vaccination coverage achieved 91 unit from 48 unit. Although vaccination coverage increased, it is clear that there is nearly no effect on the change in child diarrhea mortality happened between 2000 and 2017. This, however, does not mean that we question the effectiveness of the vaccination.

Table 21. . Rotavirus vaccines completed dose (RotaC) immunization coverage among 1-year-olds (%)

Parent Location	Location type	Spatial DimValueCode	Location	Period	FactValueNumeric
Africa	Country	LBR	Liberia	2017	71,00
Africa	Country	LBR	Liberia	2016	48,00
Africa	Country	ZWE	Zimbabwe	2017	91,00
Africa	Country	ZWE	Zimbabwe	2016	91,00
Africa	Country	ZWE	Zimbabwe	2015	87,00
Africa	Country	ZWE	Zimbabwe	2014	48,00

Source: WHO Rota-vaccine Intervention Coverage. https://www.who.int/

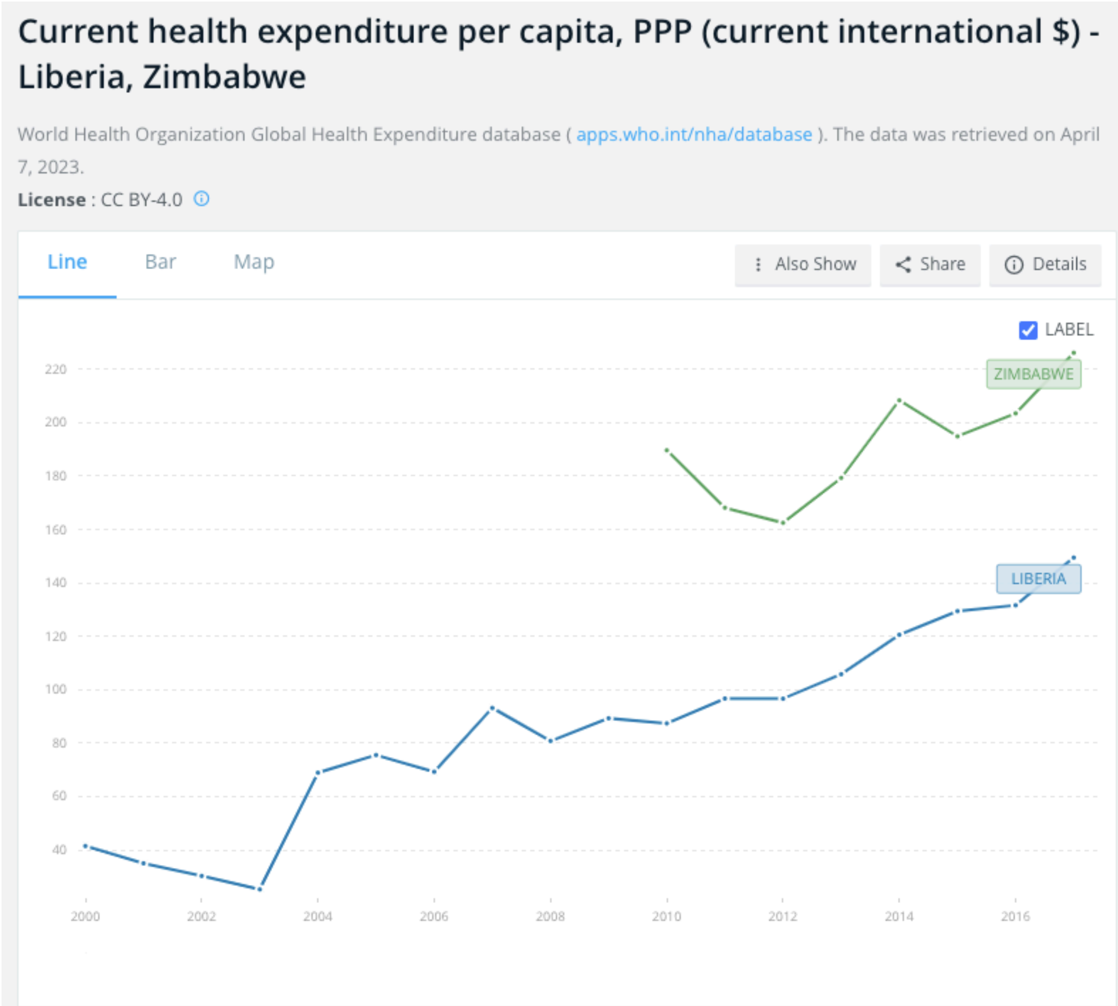
Key message 6.5.4:

There is no sign observed with regard to Rota-vaccine, thereby, it does not indicate any significant sign that weakens the likely effect of changes in water access inequality on changes in child diarrhea mortality.

6.5.5 Public Health Expenditure

As a proxy to health care variable, we considered health expenditure per capita indicator for analysis. Both countries increased their health expenditure per capita over time; however, there was a significant convergence in the amounts spent per person. As of 2017, Zimbabwe spent \$226.2 per person, while Liberia spent \$139.9. Interestingly, Liberia, despite spending a much lower amount per person on health, achieved a much higher achievement in terms of child diarrhea mortality reduction compared to Zimbabwe.

Figure 24. Health Expenditure per capita, PPP (current international $) – Liberia, Zimbabwe



Source: World Bank, World Development Indicators

https://data.worldbank.org/indicator/SH.XPD.CHEX.PP.CD?end=2017&locations=LR-ZW&start=2000

Key message 6.5.5:

As data suggests, higher health spending does not necessarily lead to better health outcomes, such as child mortality reduction. This suggests three messages. First, the differences in health expenditure per capita does not hint on weakening the likely effect of water access inequality on child diarrhea mortality. Second, a higher per capita health expenditure does not correspond to successful reduction of mortality in the case of the selected countries, which suggests that an efficiency of resource allocation is worth to be considered. Third, although an increase in health expenditure was observed in both countries, their achievements differed in terms of child diarrhea mortality.

6.6 Summary

In this chapter, we investigated water access inequality variable in a qualitative fashion with the two-stages approach in order to test whether there is an association between changes in water access inequality and changes in child diarrhea mortality happened between 2000 and 2017. The chapter started by defining a global trend, patterns, success and failure in child diarrhea mortality. It then investigated the key determinants in the case of Liberia as a success and Zimbabwe as a failure.

The first stage of the analysis reveals two important findings. *First*, majority of the countries have improved water access inequality, while dropping their child diarrhea mortality rates. This supports the hypothesis that there is a likely association between changes in water access inequality and changes in child diarrhea mortality. *Second*, A few outliers are also identified, which induced the following discussion. These outliers managed to reduce child diarrhea mortality rates without a change or with increases in water access inequality. For example, Turkey and Bangladesh had initially (as of 2000) a very high coverage rate of basic water access, which was the reason why water access inequality did not change until 2017. On the other hand, Rwanda and Angola increased inequality in water access, while dropping child mortality.

However, a presence of such the outliers does not necessarily contradict our hypothesis because of the complexity of child mortality study. This is evident in both pairs. For the cases of Turkey and Bangladesh, no change in inequality is not a negative indication given that they had initially a high rate of water coverage. For the cases of Rwanda and Angola, one plausible reason explains this seemingly puzzling pattern is that the effect of *increases in water access inequality* on *child diarrhea mortality* is absorbed in the effects of other key variables, which jointly come into play, as theoretically underpinned in Chapter 2. In this case, we still could hypothesize that an increase in water access inequality may hinder the efforts to reduce child mortality. This is, then, in line with our key hypothesis about a likely significant association between water access inequality and child diarrhea mortality.

In addition, the cases of Rwanda and Angola suggest future research direction to investigate the effects of *water access inequality* on *child mortality inequality*, in order to better understand how changes in differing access to water across socioeconomic groups affect the changes in differing rates of child diarrhea mortality across socioeconomic groups.

This necessity is evident in dissecting the mechanism through which the likely effect is maybe transmitted. That is, if an increase in water inequality happened due to an increase in water coverage for the rich and a decrease in water coverage for the poor. In this case, the rich gains health, while the poor loses health. Then health gain of the rich may offset health loss of the poor, which, in turn, appears as a net health gain for the general population, on average, if the outcome variable is the rate of mortality.

The second stage focused on a comparative analysis of Liberia and Zimbabwe to reveal whether water access inequality was the factor in their success and failure in reducing child mortality between 2000 and 2017. In doing so, we select the key variables for inclusion by evaluating whether a variable under question is theoretically well grounded. Thus, four other key determinants of child diarrhea mortality, apart from water access inequality, are selected in this in-depth comparative analysis. Which includes economic growth, female education, Rota-vaccine, and public health expenditure.

The key finding reveals that decline in water access inequality matter for decline in child diarrhea mortality. On the contrary, we did not find any sign weakening the likely association between water access inequality and child diarrhea mortality from analyses of GDP growth and per capita income, female education, Rota-vaccine, and health expenditure per capita.
Hence, these results suggest that *positive progress in water access inequality* coincides with *success in mortality decline* through the case of Liberia, whereas *negative progress in water access inequality* coincides with *failure in mortality decline* in the case of Zimbabwe.

Chapter 7

Conclusion, Future Research Direction, and Policy Implications

7.1 Conclusion & Future research direction

It is known that the role of adequate water access in child health and survival is vital, and its biological transmission channels are well clarified. However, whether and how the distribution of water access affects child mortality (i) and its economic transmission channel (ii) are unclear (Besnier et al., 2021; Fink et al., 2011; Hoddinott, 1997; Setty et al., 2020, 2019). In particular, child mortality caused by diarrhea received nearly no attention in the literature, despite only one recent study (Local Burden of Disease WaSH Collaborators, 2020).

The dissertation project aimed to address this gap by clarifying the theoretical/ conceptual background of both child mortality and water access inequality (i) and by generating robust empirical evidence on whether water access inequality is a significant determinant of child diarrhea mortality in the context of low-and-middle-income countries by applying a mixed methods approach (ii).

To this end, Chapter 2 built a theoretical background of the analyses by reviewing the relevant literature. It hypothesizes that water access inequality may be a significant factor in child diarrhea mortality as the role of water in child mortality is significant. The likely child mortality effects of water access inequality seem to be transmitted through poverty in the context of low-and-middle-income countries as the notion of inequality is highlighted in his work (Deaton, 2003).

It first set a story for the relationship between health and economic development through a political economy lens (i), clarified the determinants of child mortality from a health economics perspective (ii), clarified socioeconomic inequalities in water access from a welfare economics perspective (which is in line with the estimation method utilized in quantifying water access inequality) (iii), highlighted a plausible economic transmission channel (aka., pathway) through which this likely effect may be transmitted (iv). In addition, the relevant empirical studies are also surveyed to help making an informed decision on choosing a right estimation technique. As a result, we selected - concentration index – as a preferred approach to socioeconomic inequality, in comparison to the alternative approaches such as human opportunity index (Equality of Opportunity theory) and Gini index (v).

Chapter 2 contributes the existing literature by attempting to clarify a conceptual background of water access inequality, which is often neglected in the published empirical studies, alongside highlighting an economic transmission channel through which the likely effect of the proposed explanatory variable transmits to child mortality outcome. Moreover, clarifying a health economics approach to child mortality is an added value, given that the study of child mortality is interdisciplinary in nature and a myriad of existing studies are approached from various different perspectives such as epidemiology, public health, social science, development studies, welfare economics, historical and neoclassical economics. Last but not least, this conceptualization as a whole is unique itself, given that an intersection of water and health research approached from an economics perspective is rare, not to mention its attempt to integrate the notion of distributive justice into the key explanatory variable.

Chapter 3 describes the research design and methodology in detail. Since the dissertation heavily built up on complex quantitative estimations including a new application of concentration index approach to water with large N country cases, we systematically discussed the relevant details of the techniques in Chapter 3 rather than simply moving it to appendix.

Subsequently, Chapter 4 constructed the water access inequality index (WII) by applying concentration index approach (Filmer and Pritchett, 2001; Kakwani et al., 1997; O'Donnell et al., 2007; Wagstaff et al., 1991a) for three reasons: firstly, assessing the trends and patterns; secondly, creating international ranking in progress towards closing water access inequality in 61 countries in our sample; thirdly, most importantly, to allow analyses for its likely effect on child mortality outcomes in Chapters 5 and 6. The key dataset used for this purpose was data on water access – wealth quintile from WHO-UNICEF/JMP. The key finding suggests that water access inequality decreased in most countries at a different rate between 2000 and 2017, yet it prevails disproportionally across the world, indicating that global efforts improved the coverage of basic water access in low-and-middle-income countries over the past 2 decades.

However, there are remaining inequalities within and between countries mirroring uneven progress in a key indicator of global development.

In doing so, it applies a concentration index approach by borrowing from health inequality research and then presented the global trends and patterns of water access inequality of 61 countries. This further allows building correlations between WII and health variables in the next Chapters. For this reason, we estimated 1098 data points in order to build a panel of water access inequality for 61 countries and 18 years. The *main contribution of Chapter 4* is twofold. It generates a new panel data allowing a quantitative analysis to explore its effect (i). It also adds to the literature by providing a robust estimation of WII by exploiting the latest available datasets and more effective approach, which is borrowed from health inequality research (ii).

Chapter 5 investigated whether water access inequality is significantly positively associated with child diarrhea mortality outcomes from a health economics perspective by constructing various panel econometric models. In doing so we tested the hypothesized relationship on two mortality outcomes: child diarrhea mortality age under 5 (i) and infant diarrhea mortality (ii). Our robust findings suggest that child (and infant) diarrheal mortalities are significantly positively associated with water access inequality (H-1). In doing so, we built the panel by combining all available real-world data from major international datasets such as the Institute for Health Metrics and Evaluation (IHME), WHO-UNICEF/JMP, World Development Indicators, and Human Development Indicators.

The key contribution of Chapter 5 is bringing a new explanatory variable – water access inequality – into the debate on global child mortality in which we recognize the role of the distribution of water access for child survival in LMICs. The current debate is concentrated on three key determinants: the role of an economic change, a social change (endorsed by a change in female education), and a medical technology change (Jamison et al., 2016). Initially, the explanations were competing, yet the view has eventually changed to become complementary to each other. *Second,* the study addressed the limitations of previous studies by constructing multi-country panel, which improved the quality of the analysis by relying on a large N panel of observation rather than a small cross-sectional observation such as (Hasan and Alam, 2020) and a repeated cross-sectional observation such as (Cha et al., 2017). *Third,* a new dataset of IHME is used, which allows for investigating the cause-specific-mortality variables in the context of LMICs, which had not been possible until recently. *Fourth,* we took three important measures in order to improve efficiency and accuracy of the panel models. First, we interpolated missing variables where needed in line with important literatures (Anand and Bärnighausen, 2004; Jamison et al., 2016). Thereby, it balances the panel and avoids from omitting important information due to a data gap. *Fifth*, the fixed-effects model is extended by including time-fixed-effects (Greene, 2003) (i) and Driscoll-and-Kraay standard errors (Hoechle, 2007) (ii) and performed robustness checks (iii) in the end. Hence, the results are robust.

To complement the findings of Chapter 5, we applied a comparative case analysis in Chapter 6. Through two-stages analysis, we tested whether there is an association between changes in water access inequality and changes in child diarrhea mortality (age under 5) happened between 2000 and 2017 in LMICs. It begun by identifying global trends, patterns, and 'success' and 'failure' in reducing child mortality based on the international ranking produced. Then, it then focused the cases of Liberia and Zimbabwe in-depth. The first stage of the analysis presents the following findings.

- Decreases in water access inequalities are significantly positively associated with success in child mortality reduction **(H-2.1)**
- Increases in water access inequalities are significantly positively associated with failure in child mortality reduction **(H-2.2).**
- Absence of progress in water access inequalities (WII) is significantly positively associated with *success* in child diarrhea mortality (CDM), if the absence of change in WII is due to the presence of a high initial coverage of water **(H-2.3).**
  Conversely,
- When investigating two outliers, we fail to reject the null hypothesis of the H-2.4: Absence of progress in water access inequalities (WII) is associated with failure in child diarrhea mortality (CDM), if the absence of progress in WII is due to the absence of improvement towards full coverage of water **(H-2.4).**
- This suggests that water inequality effect can be camouflaged when testing on the total mortality data. Because we found evidence indicating (WII) inequality increased due to increased coverage for rich and decreased coverage for poor. In this case, the rich gains health, while the poor loses health, given that water and health are directly associated. In this case, health gain of the rich may offset health loss of the poor, which in turn appear as a net health gain for the general population. It, therefore, does not necessarily contradict the hypothesis on the relationship between water inequality -

child mortality. (In addition, one more plausible explanation is that the effect of increases in water access inequality on child diarrhea mortality maybe absorbed in the effects of other key variables, which jointly come into play, as theoretically underpinned in Chapter 2 and tested quantitatively in Chapter 5.)

At the second stage, we tested H-2.1 and H-2.2 for Liberia and Zimbabwe (instead of Kazakhstan, Liberia is opted for a success case because of comparability considerations). The results suggest that positive progress in water access inequality coincides with success in mortality decline through the case of Liberia, whereas negative progress in water access inequality coincides with failure in mortality decline in the case of Zimbabwe. Moreover, we did not find any sign weakening the likely association between water access inequality and child diarrhea mortality from analyses of GDP growth and per capita income, female education, Rota-vaccine, and health expenditure per capita.

Our study has also several limitations. *First*, the findings may not be useful to inform policies concerning water access inequalities caused by ethnic, racial, and geographic stratifiers. *Second*, a panel approach does not address causality in the relationship, although it can address endogeneity at a certain extent. It, therefore, suggests a further investigation seeking causality. Although attempts made, our study was unable to address causality due to the problems relating to data in hand. *Third,* Rotavirus vaccine is excluded in the model due to the lack of sufficient data because it is one of the new and under administrated vaccines compared to other routine vaccines such as DPT3 (which is irrelevant to diarrheal infection). Therefore, the status of vaccination has not allowed an accumulation of necessary data, which is suitable for the design of our study. However, it seems has not administered to the countries long enough, as WHO - vaccination coverage data tells, thus its likely effect, particularly during the period covered in our analysis, is assumed to be not malignant to our results. *Fourth,* we acknowledge that there is a difference between the classifications of water access: safe and basic. When possible, the data on safe water access should be tested to confirm whether the findings hold true. Therefore, the relevant policy implications have to be carefully formulated considering these limitations.

In contribution to future research direction, in addition to above formulated suggestions, several questions deserve scholarly attention: whether and extend to which official development assistance matters for water access inequality; why water access inequalities increased in some countries, while others managed to decrease it; and how water access inequalities affect child mortality inequalities - that is to better understand how changes in differing access to water across socioeconomic groups affect the changes in differing rates of child diarrhea mortality across socioeconomic groups because of the finding relating to H-2.4.

7.2 Policy Implications

Our results imply that water access inequalities matter for child diarrhea mortality (i), and water access inequalities may hinder progress towards reducing child diarrhea mortality (ii).
Based on these findings the following policy implications are carefully formulated.

- First, prioritizing pro-poor investment for water infrastructure is necessary for closing the existing gap in LMICs. Official development assistance should consider this condition in its financing requirements at least proportionally, if not exclusively. Its expected impact is to create an external constraint for the decision makers for inclusive development in terms of the coverage of adequate water access, thereby promoting a preventive strategy in child health in order to reduce child mortality caused by diarrhea.

In addition to the implication on the key outcomes, several ideas need to be communicated relating to the policy-relevant variables, controlled in the analytical models. The results of the quantitative analysis show that

- Nutrition is one of the key variables, alongside female education. Just improving knowledge about nutrition and hygiene, especially for girls and mothers, would potentially improve child mortality outcomes even without changing the levels of current resources.
- Although big and strong, the income effect is offset by the income inequality effect. This suggests that the poor is left behind, not benefitting from the gains of globalization and the positive impact of economic growth. It seems necessary to attack income inequality in order to achieve the desired yet interconnected child mortality outcomes. However, it needs more thorough research.

All in all, child mortality particularly caused by a preventable disease such as diarrhea is not only devastating for those who are affected but also has a negative effect on economic development.

Appendixes

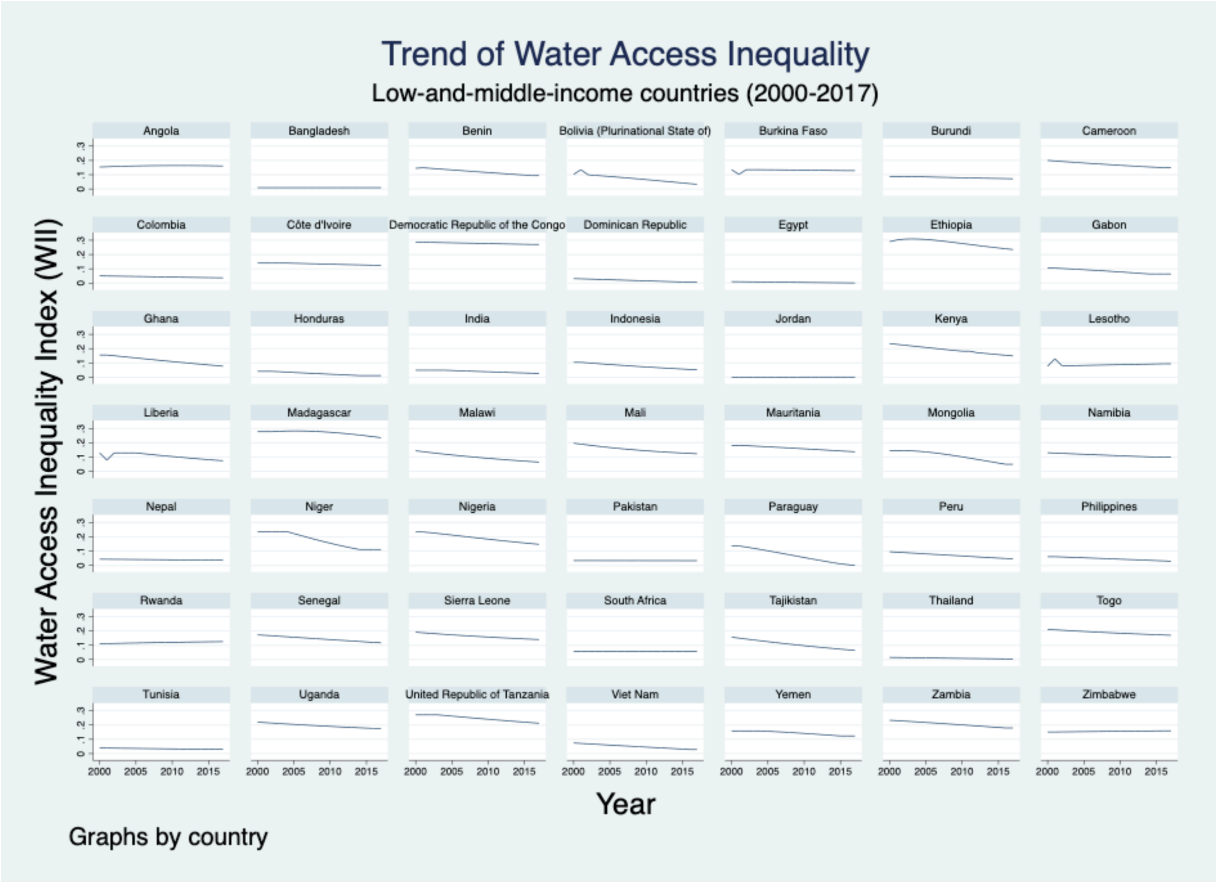
Appendix 1. Matrix of correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) log_cmdu5	1.000																
(2) log_cmdu5f	0.994	1.000															
(3) log_cmdu5m	0.996	0.981	1.000														
(4) log_cmdu1	0.991	0.986	0.986	1.000													
(5) log_cmdu1f	0.983	0.990	0.969	0.994	1.000												
(6) log_cmdu1m	0.988	0.974	0.992	0.996	0.980	1.000											
(7) log_ciwat	0.645	0.623	0.657	0.621	0.598	0.632	1.000										
(8) log_cisan	0.503	0.502	0.496	0.483	0.482	0.478	0.677	1.000									
(9) log_gdpcapi	-0.671	-0.658	-0.675	-0.631	-0.613	-0.639	-0.536	-0.289	1.000								
(10) log_ginii	0.016	0.006	0.029	0.043	0.035	0.054	0.146	0.173	0.198	1.000							
(11) log_fedu1i	-0.625	-0.624	-0.622	-0.567	-0.561	-0.569	-0.467	-0.330	0.703	0.206	1.000						
(12) physcapi	-0.665	-0.641	-0.677	-0.655	-0.628	-0.671	-0.497	-0.537	0.576	-0.064	0.484	1.000					
(13) L.log_hecapi	-0.667	-0.653	-0.669	-0.616	-0.598	-0.623	-0.519	-0.343	0.895	0.294	0.680	0.534	1.000				
(14) log_ors	-0.310	-0.297	-0.318	-0.273	-0.262	-0.281	-0.218	-0.077	0.213	0.057	0.330	0.150	0.246	1.000			
(15) log_cereal	-0.455	-0.455	-0.451	-0.442	-0.441	-0.438	-0.455	-0.195	0.431	-0.078	0.461	0.270	0.302	0.183	1.000		
(16) bfp	0.085	0.107	0.065	0.070	0.092	0.052	0.087	0.097	-0.301	-0.061	-0.061	-0.155	-0.270	0.064	0.105	1.000	
(17) log_urbanpop	-0.459	-0.452	-0.459	-0.444	-0.431	-0.449	-0.335	-0.156	0.747	0.228	0.623	0.507	0.681	0.021	0.213	-0.370	1.000

Appendix 2. **Variance inflation factor: Model - 1**

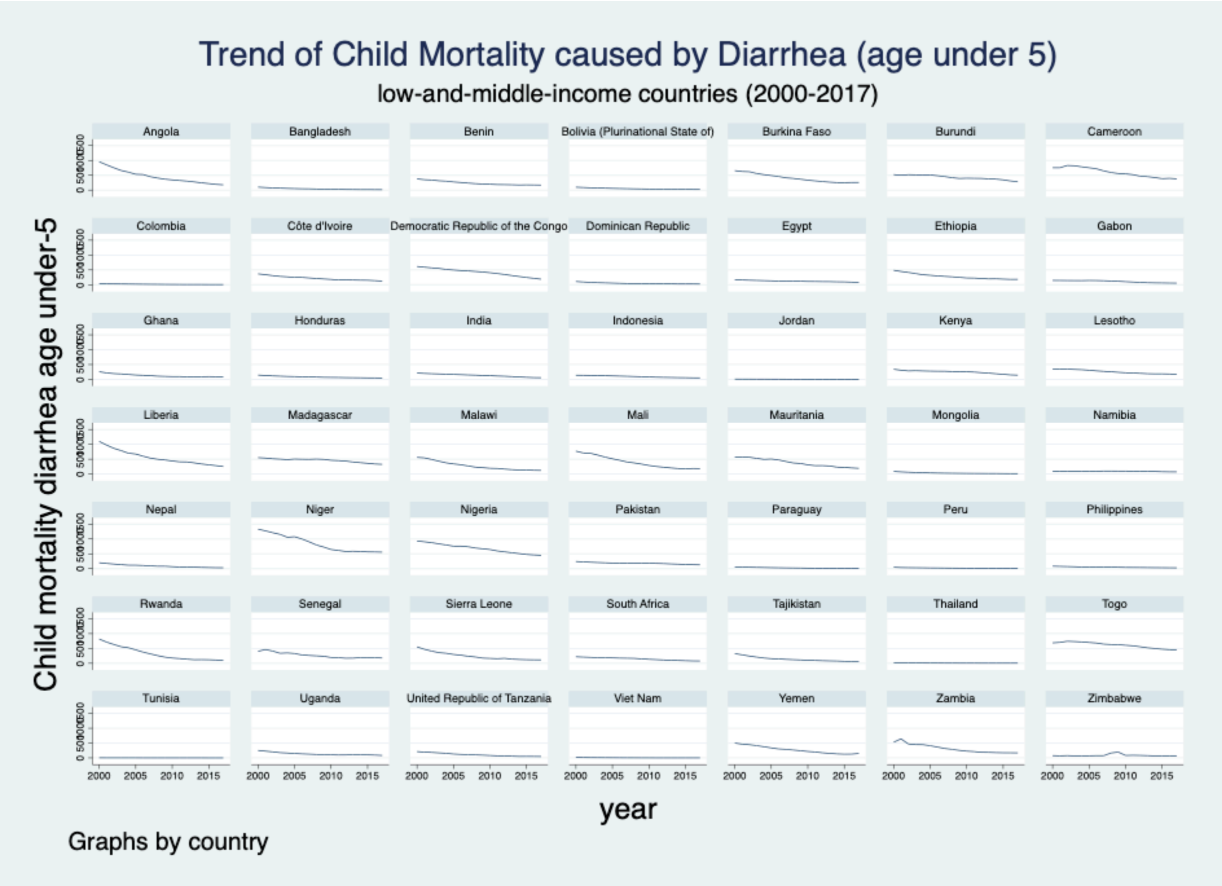
Variable	VIF	1/VIF
log_ciwat	2.89	0.346166
log_cisan	2.59	0.386206
log_gdpcapi	8.22	0.121619
log_ginii	1.51	0.661874
log_fedu1i.	2.91	0.343777
physcapi	2.25	0.443931
L1. log_hecapi	6.61	0.151370
log_ors	1.30	0.768903
log_cereal	1.72	0.579942
log_urbanpop	3.18	0.314500
bfp	1.47	0.680171
year		
2002	1.88	0.530895
2003	1.89	0.530287
2004	1.89	0.528726
2005	1.90	0.526260
2006	1.91	0.523178
2007	1.93	0.518472
2008	1.95	0.512427
2009	1.97	0.508747
2010	1.98	0.504426
2011	1.99	0.502708
2012	2.01	0.498575
2013	2.02	0.494061
2014	2.05	0.488517
2015	2.04	0.490580
2016	2.05	0.487847
2017	2.04	0.489814
Mean VIF	2.45	

Appendix 3. Trend of Water Access Inequality across low-and-middle-income countries 2000-2017



Source: Own construction. Water Access Inequality Index across 61 low-and-middle-income countries, estimated based on the JMP datasets on water access.

Appendix 4. Trend of Child Mortality caused by diarrhea age under 5 across low-and-middle-income countries 2000-2017, by countries



Source: Own construction. Child diarrhea mortality age under 5 across 61 low-and-middle-income countries, estimated based on the IHME datasets.

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