Data Visualization and Power of Evidence-Based Policymaking in Countries in Transition[1]

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Abstract: The purpose of the paper consolidating talks presented in an ASA panel is to investigate merits and drawbacks of data visualization and power of evidence-based approaches to addressing public policy issues in countries in transition. We discuss overarching analytical problems and the value of using data visualization when it comes to addressing policy issues in public health, economics and education among developing countries in particular. The paper demonstrates case studies of how data-poor countries can address national problems by leveraging multiple sources of data, vitalizing data visualization and supporting evidence-driven policy development. Case studies utilize the UN Millennial Development Goals data, UNICEF and WHO data, and survey and census data collected from developing countries, including Democratic People's Republic of Korea[2] (DPRK, also known as North Korea).

Key Words: data visualization, evidence-based policymaking, multiple sources of data

1. Introduction

In the last few decades, evidence-based policymaking has become an important topic in the conversations among government agencies, research organizations, and think tanks. Evidence-based policymaking utilizes evidence from research to inform the policymaking process, which intends to bring about social, economic, and fiscal benefits. Data visualization is the use of electronic tools to promote accurate comprehension of massive data. Researchers can create data visualizations to communicate their messages about health, social, and economic policy issues in developing countries. In this paper, we aim to demonstrate the power of data visualizations as an evidence-based approach to policymaking. To that end, we create static and interactive visualizations of data from

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[1] The views expressed are those of the authors and not necessarily those of the listed institutions. All authors are also affiliated with the PSI Institute for Data Science and Interdisciplinary Research. The PSI is part of the International Strategy and Reconciliation Foundation, a 501(c)(3) non-profit organization based in the Washington metropolitan area.

[2] The DPRK survey data used for the paper will be publicly released in the ISR Foundation website, www.isr2020.org.

multiple sources, including survey data, census, and administrative records. We discuss the way in which data visualizations may help the United Nations and non-governmental agencies develop evidence-driven decisions for sustainable development programs.

2. Major Policy Issues in Developing Countries: Public Health, Economics and Education

It is undeniable that the world has made incredible progress in striving to achieve the Millennium Development Goals set in 2000. Nonetheless, there still remains much work to be done in a variety of areas, with some regions struggling more than others. We review in this section major social, economic and public health issues that affect the condition and progress of the nation's wellbeing with our focus particularly on developing countries. We set the stage to learn what real-world problems we are facing before we delve into discussing how evidence-based policymaking can be empowered by a tool of data visualization even among data-poor countries. The reader may find Figures 1 through 18 used in this section in Appendix. (United Nations, 2015)

2.1 Poverty and Hunger

The world met the target of halving the proportion of people living in extreme poverty in 2010, five years ahead of schedule (Appendix Figure 1). However, certain regions have lagged behind more than others. For examples, sub-Saharan Africa is essentially the only region in the world that did not meet its 2015 target for reducing the extreme poverty rate. Although Southern Asia met its target on time, there is still a large number of extremely poor in the region; in fact, 80% of people living in extreme poverty are from sub-Saharan Africa or Southern Asia (UN, 2015). Additionally, women face a greater risk of living in poverty. As Figure 2 shows, in 41 countries women are more likely to live in poor households than men.

According to the 2010 UNDP report *What Will it Take to Achieve the MDGs?*, 1.02 billion people were undernourished worldwide. That figure has fallen to 795 million (UN, 2015). Once again, certain regions fared more poorly than others: sub-Saharan Africa and Southern Asia did not meet their 2015 target for reducing the proportion of undernourished people and the two regions account for almost 90% of the world's underweight children. The Caribbean, Oceania, and Western Asia also failed to meet the target (UN, 2015) (Figure 3).

Overall, much progress has been made to decrease the proportion of people living in extreme poverty and hunger. However, in order to achieve the goal of complete eradication, the world faces many obstacles and challenges.

2.2 Gender Inequality

In 2010, many countries struggled with gender inequality, especially in employment. For example, in Egypt, the unemployment rate for women was 4 times the unemployment rate for men and in Nepal, men earned 45% more than women (UNDP, 2010). These problems remain in 2015. Globally, about 75% of working-age men participate in the labour force compared to 50% of working-age women (Figure 4), and women earn 24% less than men. Participation of women in the labour force is particularly low in Northern Africa, Western Asia, and Southern Asia, due to cultural constraints, household responsibilities, and other factors (UN, 2015).

2.3 Child Mortality

The UN MDG targeted to reduce child mortality by two-thirds by 2015. Although substantial progress has been made in reducing child mortality, with the trends that currently exist, it will take another ten years for this target to be reached. More children can and need to be saved from preventable deaths. Furthermore, socioeconomic disparities cause different rates of child mortality as seen in Figure 5. Lastly, measles immunizations have saved millions of children's lives, however, as seen in Figure 6 progress in implementing immunizations has stalled since 2010. Thus, between 2012 and 2013, the cases of measles actually increased.

2.4 Maternal Mortality

The maternal mortality ratio has decreased by 45% worldwide. However, there are disparities in access to maternal health care across different regions as seen in Figure 7. Sub-Saharan Africa and Southern Asia also have trouble with maternal mortality. The two regions accounted for 86% of the world's maternal deaths in 2005 and in 2013 (UNDP, 2010 and UN, 2015)

Furthermore, only half of pregnant women receive the recommended amount of antenatal care (Figure 8). In order to assure a safe delivery, the U.N. recommends four appointments in order for the mother to receive a basic care package and to detect any warning signs early on. Unfortunately, there is a lack of basic data on births, deaths, and health. Globally, only 51 percent of countries have some data on maternal causes of death which prevents effective policies from being created.

2.5 Epidemic Disease

One of the major goals of the UN has been to combat the major diseases impacting the global community. At the time when the MDGs were drafted in 1990, HIV/AIDS, malaria, and tuberculosis were considered the most urgent of issues to be addressed. Since then, the number of HIV related deaths has declined and the number of people with the necessary treatment has increased. Figure 9 shows that the number of AIDS related orphans has been decreasing since 2009.

Still, the problem is heavily concentrated in sub-Saharan Africa, millions of orphans still need protection, and knowledge of disease prevention is low. The bar graph in Figure 10 depicts two things: comprehensive correct knowledge of HIV and actual use of condoms during higher-risk sex. As we can see, although men are relatively more educated on the issue, the general percentage of awareness remains quite low.

Another disease that has been a part of the UN agenda is malaria. The global incidence rate has decreased by 37%. In Figure 11, the proportion of children sleeping under insecticide-treated mosquito nets in some countries in sub-Saharan Africa has increased drastically. As a result of such prevention efforts, the general trend of malaria incidence rate (in blue) and malaria mortality rate (in red) has been decreasing steadily since 2000 (Figure 12). Still, malaria remains a public health challenge, and only 20% of children with fever receive a malaria diagnostic test.

Tuberculosis is the third and final disease that was officially a part of the MDG goals. The incidence, mortality, and prevalence rate of tuberculosis has all been falling due to effective prevention, diagnosis, and treatment. As seen in the graph on the left of Figure

13, the incidence trend and mortality trend has been steadily falling since 1990. Prevalence of TB has especially decreased significantly. In other words, less people have gotten TB or died from it, but TB cases are more concentrated in certain areas. Still, in developing regions, where TB poses the highest threat, more than 85% of newly diagnosed cases have been successfully treated for 6 consecutive years, as shown in light blue in Figure 14.

2.6 Environmental Sustainability
The UN has also tried to attain a certain level of environmental sustainability over the past couple decades. Success has definitely been achieved on many fronts. Just to name a few, net deforestation has slowed, the ozone layer is expected to recover by mid-century, and 91% of the world's population is using an improved water source. But the problems that exist need immediate attention.

Global greenhouse gas emissions continue to rise. According to the MDG Report 2015, global greenhouse gas emissions were over 50% higher in 2012 than they were in 1990. Figure 15 is a graph of the emission of carbon dioxide. The bar graph show the extent to which the world as a whole, and especially developing nations, has contributed to global carbon emissions in the past two and a half decades.

Overexploitation of marine fisheries is also rising. Figure 16 is a graph illustrating the current status of the marine fisheries. The actual number of fish landings is increasing, but the fish stock within their safe biological limits is decreasing. Loss of biodiversity continues to be a struggle for the world's species. As depicted in Figure 17, birds, mammals, corals, amphibians and cycads (psych-add) have all been experiencing a downward trend towards loss of diversity. This has especially been dramatic for corals, seen in a line graph highlighted in orange.

Water scarcity is also an important environmental issue, affecting more than 40% of the world's population. Northern Africa, Western Asia, Caucasus and Central Asia, and Southern Asia are the most affected regions (UN, 2015). The *What Will it Take to Achieve the MDGs?* report states that up to 250 million people in sub-Saharan Africa will be at risk of increased drought in 2020, which will certainly worsen the problem of water scarcity (UNDP, 2010). Although there have been developments regarding basic sanitation and use of improved sanitation facilities, huge disparities exist between the rural and urban communities. Figure 18 shows the difference in proportion of population using improved drinking water sources (in blue) and sanitation facilities (in red) in urban and rural populations as well as the world in general. On the left, the darker the blue the better, and on the right, the lighter the red the better. In urban communities (the leftmost blue and leftmost red) the colors show a majority of dark blue or light red. However, the world average is brought down significantly by the rural areas, whereas urban areas maintain relatively good conditions.

2.7 Setbacks Due to Crises, Shocks, and Vulnerabilities
Various unexpected events, such as the 2008 economic and financial crisis and the 2014 Ebola outbreak, have hindered progress in the Millennium Development Goals.

Many sub-Saharan African countries were severely affected by the economic crisis. Botswana's GDP decreased by 5% by March 2009 and unemployment in the mining sector had risen by 9.3%; 45 000 people lost jobs in South Africa, where manufacturing

output fell by 25%; 100 000 people lost jobs in DRC; 6000 people lost jobs in the mining sector in Zambia in November 2008; and unemployment increased 6.4% between 2008 and 2009 in Lesotho. Countries that depend mainly on primary commodities for exports, such as Angola, Sierra Leone, Equatorial Guinea, Sudan, and Chad, are particularly vulnerable to economic crises (UNDP, 2010).

One of the worst international public health emergencies was the 2014 Ebola crisis in West Africa. The outbreak was worsened by poor health infrastructure, air travel, and a number of other factors. Although the outbreak has been dealt with, its effects reached beyond those of public health. Millions of children could not attend school, and health facilities and services fell apart during the crisis (UN, 2015).

Many developing countries are vulnerable to natural disasters. Agricultural activities are affected by floods and droughts. In Nepal, women make up 73% of the workforce in agriculture, so natural disasters affect them unequally. In Ghana, as a result of flooding, child under-nutrition increased from 15.6% in 2006-2007 to 45.5% in 2007-2008. As the effects of climate change worsen, the frequency of natural disasters will increase (UNDP, 2010).

Finally, conflict is another major factor that has greatly hindered progress in achieving the MDGs. The proportion of undernourished people in Western Asia was projected to increase by 32% between 1990-1992 and 2014-2016 due to conflict, which includes "war, violence, and high levels of crime." Specific countries that have struggled with conflict are Iraq, Nigeria, Syria, Pakistan, South Sudan, Ukraine, and the DRC, among others. Conflicts have led to many refugees leaving their countries; by the end of 2014, 7.6 million fled from just three countries: Syria, Afghanistan, and Somalia (UN, 2015). Conflict in the Central African Republic caused the already high poverty rate of 70% to rise even further, and over half of the population in the capital city is in need of humanitarian aid (Fast Facts, Elliott). Furthermore, in many countries affected by conflict, the proportion of out-of-school children increased between 1999 and 2012. Northern Africa and Southern Asia saw particularly large increases in this proportion. Syria has especially struggled in improving enrolment rates due to conflict: "enrolment rates fell by 34 percentage points for grades 1 to 12 in the school year ending in 2013." (UN, 2015)

3. The Power of Evidence-based Policymaking

In the last few decades, evidence-based policymaking (EBP) has become an important topic in the discourse put forth by government departments, research organizations, and think tanks. For example, Sutcliffe & Court (2005) pointed out that EBP was embraced in the United Kingdom in 1997, which marked the end of "ideologically-driven politics" and the entry of rational decision making. Since then, emphasis on EBP has grown in the UK and led to the development of a wide variety of tools used by the UK government, notably the Magenta Book and the Green Book (Sutcliffe & Court, 2005). On the other side of the Atlantic, the Obama administration developed and implemented six evidence-based initiatives, covering various areas of social intervention: teen pregnancy, maternal support, education funding, social innovation funding, and workforce funding (Haskins & Baron, 2011). Research organizations and think tanks, such as the Brookings Institution and the Heritage Foundation, published papers highlighting the role of EBP as the crucial factor in the success of Congress' spending decisions and federal social programs (Baron

& Haskins, 2011; Liebman, 2013; Muhlhausen, 2015). It appears that EBP is a valuable tool in the policymakers' toolbox.

3.1 Defining Features of Evidence-Based Policymaking

In order to deepen our discussion of the value of EBP, we first give its definition. Simply put, EBP utilizes evidence from research to inform the policymaking process. It was regarded a method that "helps people make well informed decisions about policies, programmes and projects by putting the best available evidence from research at the heart of policy development and implementation" (Davies, 2004). It was also called "the integration of experience, judgement and expertise with the best available external evidence from systematic research" (Davies, cited in Sutcliffe & Court, 2005). Indeed, the power of EBP lies in its methodical approach to policymaking, an approach that rendered opinion-based policymaking ineffective. According to the literature, this advantage of EBP over the obsolete opinion-based policy making could be shown in three aspects: social, economic, and fiscal benefits. The following discussion of these three types of benefits echoes the arguments made by Baron & Haskins (2011), Liebman (2013), and Muhlhausen (2015).

First, the social benefit of EBP could be reaped by collecting high-quality evidence on the effectiveness of social programs. In the United States, there is a dire need for such evidence, since many social programs are not evaluated for their effectiveness (Liebman, 2013; Muhlhausen, 2015). Scientifically rigorous evaluations of programs would reveal programs that work, as well as those that fail. Policymakers can then eliminate programs with mediocre results, and expand programs that are effective. Second, expanding effective social programs will in turn lead to significant economic results. For example, if we expand programs that has empirically improved the education of low-income children, we will eventually close the income-based academic-achievement gaps, and fully utilize any untapped human potential. Utilizing the human resources will lead to faster economic growth (Cohen & Soto, 2007; Liebman, 2013; Mankiw, Romer, & Weil, 1992). Finally, replacing ineffective programs with effective ones will reduce government spending and debts. In 2015, the U.S. federal government owed more than $18.1 trillion in debt (Muhlhausen, 2015). Shutting down ineffective programs will improve the allocation of scarce federal resources, and help reduce debts in the long run.

3.2 Evidence-based Policymaking in the Context of Countries in Transition

Even though the discussion of EBP so far has focused on the U.S. and the UK, many strategies of EBP can be applied to countries in transition. Since EBP is often less developed in these countries, the potential for growth is greater; in consequence, the improvement could be much more significant. However, when applying EBP to countries in transition, we should be mindful of the issues, such as political instability, conflict, academic freedom, media freedom, and civil society.

4. The Principles of Data Visualization

Data visualization can be understood as the use of electronic tools to promote accurate comprehension of data (Few, 2010). Under this definition, the role of data visualization is two-fold. First, it helps viewers achieve a clear understanding of the data. Second, it is researchers' instrument to communicate their messages about the data to the viewers. As such, works that qualify as data visualization must be informative, possessing elements

that aid cognition (Few, 2010). In view of the aforementioned role of data visualization, we present several principles of data visualization primarily based on those presented by Few (2010) in his article "Information Visualization, Design, and the Arts: Collision or Collaboration".

First, viewers can easily understand quantitative values if they are displayed using the lengths of simple, two-dimensional objects, such as bars. This method prompts the human mind to make comparisons on a one-dimensional plane (the lengths) while objects are presented on a two-dimensional surface. On the contrary, angles and areas require the human brain to make two-dimensional comparisons in a two-dimensional presentation; therefore, they tend to make it more difficult for viewers to decode the visualizations. Second, viewers cannot see a pattern formed by multiple values if they only look at one value at a time. The use of lines makes the pattern a lot clearer, especially with a set of values across a continuous range such as ages. Third, data visualizations should allow viewers to filter out data that are not of interest, so that they can focus on a subset of the data without distraction. Last but not least, when more than one variable is involved, small multiples should be used. This is the method of showing multiple graphs together, which is better than showing one single graph. Viewing the data from multiple perspectives is also useful. We apply these principles in our research, so that our data visualizations facilitate understanding of data from the UN.

5. Cognitive Aspects of Information Visualization

Research suggests that some data visualizations may fulfill their role better than the others. Specifically, data visualizations that encourage viewers' engagement with information tend to be more successful at promoting viewers' learning. The article "Benefitting InfoVis with Visual Difficulties? Provocation Without a Cause" cites the research results of psychologists Elizabeth and Robert Bjork of UCLA, which points out that students learn better when they are forced to think reflectively about the materials, instead of being given the answers (Few, 2011). As an example, when viewers are forced to explain the information they are viewing, they are also forced to think about the information carefully, which in turn facilitates their learning.

"Benefitting InfoVis" cites a theory that can explain this outcome. The premise is that people use two systems when thinking: system 1, which relies on intuition and heuristics; and system 2, which relies on careful analytical thinking. When viewers are engaged in data visualizations, system 2 are triggered, which leads to better processing of the information being presented. These results hint at the importance of interactive data visualizations. Since interactive data visualizations allow viewers to explore the data themselves, viewers establish a bond with the subject matter. This engagement stimulates viewers' active processing of the information.

6. Research Questions and Methodology

We focus on these four research questions in our paper. First, we want to know if data visualizations can advance evidence-driven policy development in countries in transition. We want to know if EBP can be applied to developing countries, and if so, what are the benefits and challenges, compared to the situation of developed countries. The second question gets at the first step in creating data visualizations: identifying and collecting

data. What data should be used to demonstrate the role of DV in EBP? If multiple data sets are available, can the data be combined? If so, how should we combine the data?

Third, we want to find a way to create DVs that may help inform the policymaking process. How can we demonstrate the power of data visualizations in advancing evidence-based policies in key areas such as public health, economics, and social issues? Last, we want to look at the merits and drawbacks of EBP and DVs, especially in the context of developing countries.

Most of the data used in this paper was obtained from the UN Millennium Development Goals database[3] and the World Bank Open Data Catalog.[4] We linked data where feasible to develop data maps and interactive DVs. Using data from multiple sources, we created data visualizations to aid in making policy recommendations and decisions regarding public health, economic, and social/education issues in countries in transition. We developed data visualizations mostly by using R. For the interactive component, we used R Shiny. We applied principles of DVs as summarized by Nguyen, Ying, Chun, et al. (2015).

An important limitation of the available data is item nonresponse. In situations where item non-response was a problem, the missing data was replaced by the most recent value for that indicator. However, some countries had no data for certain indicators that we were examining, so they were excluded in the analysis and data visualizations. This is unfortunate, as the countries which lacked data were often the ones with the most concerning issues. As a result of missing data, the sample size was not as large as we would have liked it to be.

Additionally, the quality/accuracy of the data was not always the best. For example, the World Bank had to interpolate some of its data and where this was not possible, it used the most recent value available. Despite these limitations, we still believe that the data visualizations we created can provide useful and meaningful policy recommendations for countries in transition.

7. Data Visualization Applications and Discussion

So far we have discussed the roles of data visualizations and evidence-based policymaking. The use of data visualizations can inform the policymaking process and make tremendous improvements in key areas of developing countries such as public health, economic, and social issues. In this section, we discuss selected data visualizations created in our research. It is our goal that these visualizations will demonstrate the power of data visualizations in evidence-driven policymaking.

7.1 Women's Health, Education and Political Empowerment in Developing and Developed Countries and Evidence-Based Policy Implications

The research question intends to explore whether there is an empirical relationship among women's health, education and political empowerment and, if so, investigate the extent to which the three drivers differentially affect women's status in developing and developed

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[3] http://mdgs.un.org/unsd/mdg/data.aspx
[4] http://datacatalog.worldbank.org/

countries. The three factors we have operationalized are maternal mortality, women in secondary education, and women in parliament. Studies show that slow progress for women's health in developing countries is due to prejudice against women or deprioritization of the needs of women. We used the data from the UN Millennium Development Goals to explore the relationship over time among the three factors affecting women's well-being in developing and developed countries, respectively, and connect the findings to evidence-based policymaking that may advance women's well-being.

7.1.1 Maternal mortality in developing and developed countries

Maternal mortality was chosen as an indicator for the health of a set of vulnerable women and as a data set would show a certain trend that could serve as the basis of the research question.

A set of boxplots in Figure 19 shows the maternal mortality ratio of developing and developed countries in 5 year intervals, from 1990 to 2015. The colors are added to indicate the different years.
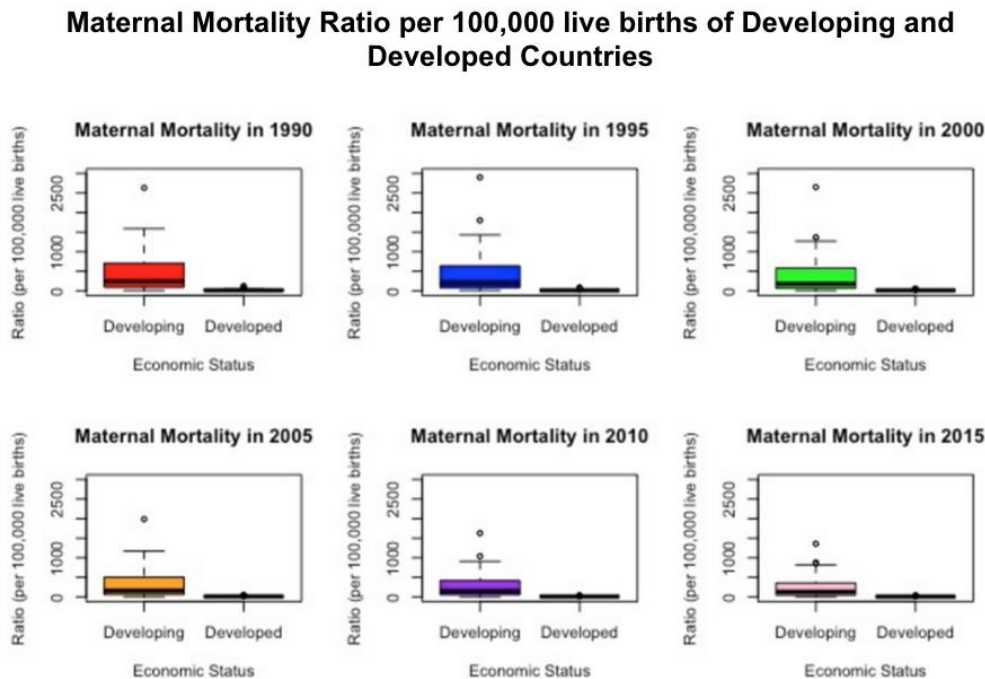
Figure 19: Maternal mortality ratio in developing and developed countries

As expected, the developing countries had a higher maternal mortality than the developed countries in each time period and across the years. When it comes to difference of maternal mortality rates in each year, the maternal mortality gap has narrowed between developing and developed countries. The progress made every five years seems to be in the right direction as advocates of women's well-being are concerned about. An intriguing point was the presence of certain outliers that needed the most support in

maternal health pressed down the maternal mortality rate from 1990 to 2015. The impact of these outliers on the average mortality rate seems to have been attenuated over time.
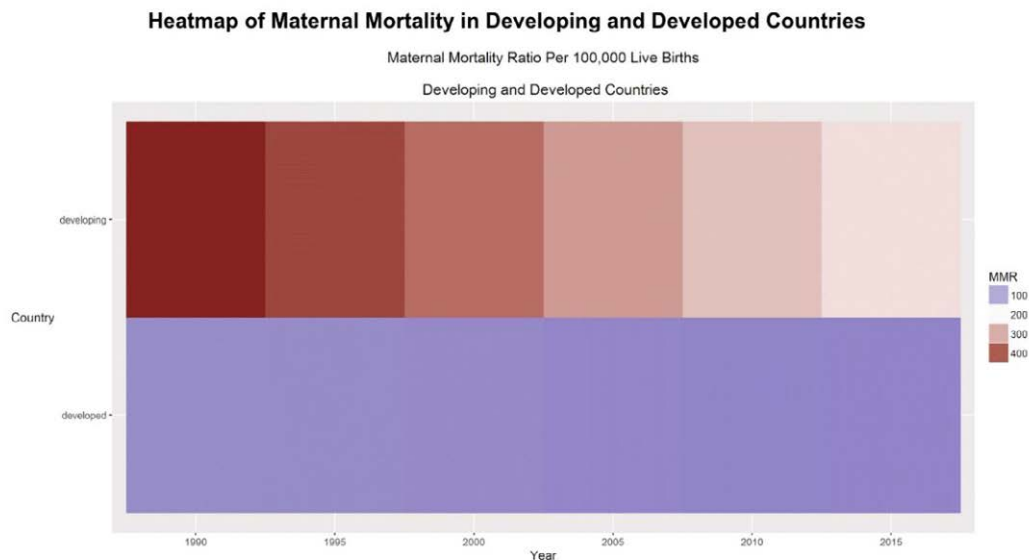
Figure 20: Maternal mortality ratio in developing and developed countries

Figure 20 visualizes the same data in heat map. This data visualization demonstrates that there was drastic improvement in developing countries over the 25 year period. In contrast, developed countries stayed at a pretty low maternal mortality rate from the beginning, with some improvement, as seen in the slightly darker hues of purple towards the end of the period under assessment.

7.1.2 Gender parity index in secondary level enrolment in developing and developed countries

The second indicator chosen was gender parity index in secondary level enrolment. This indicator was meant to show the involvement of girls in education. Whereas primary education increasingly became a given, secondary education was thought to more realistically depict the state of women's education on basic levels for this particular research question. Gender Parity Index describes a ratio, so closer to 1.0 means that men and women are equally represented. A value larger than one means that women are over-represented, and a value less than one means that women are under-represented in comparison to men.
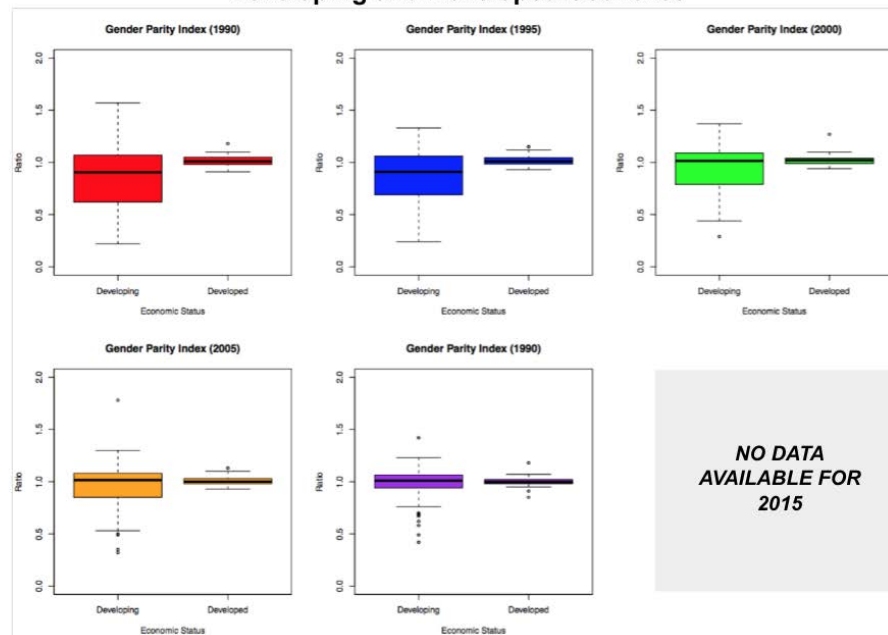
Figure 21: Gender parity index in secondary level enrolment in developing and developed countries

As Figure 21 shows, there is a huge range of gender parity for developing countries, although the average for developing and developed countries appear similar, around the 1.0 mark. There are several outliers for both developing and developed countries, whether the values are lower or higher than the average. No data was available for the year 2015.

7.1.3 Proportion of seats held by women in national parliament in developing and developed nations

Proportion of seats held by women in national parliament was chosen because political power is considered the highest level of women's empowerment by the UN. The UN has five sets of data regarding female empowerment: girls in primary school, girls in secondary school, girls in tertiary or higher education, women in non-agricultural sectors of occupation, and women in national parliament. This particular indicator was initially chosen to see whether slow progress for women was due to lack of political representation on their behalf.
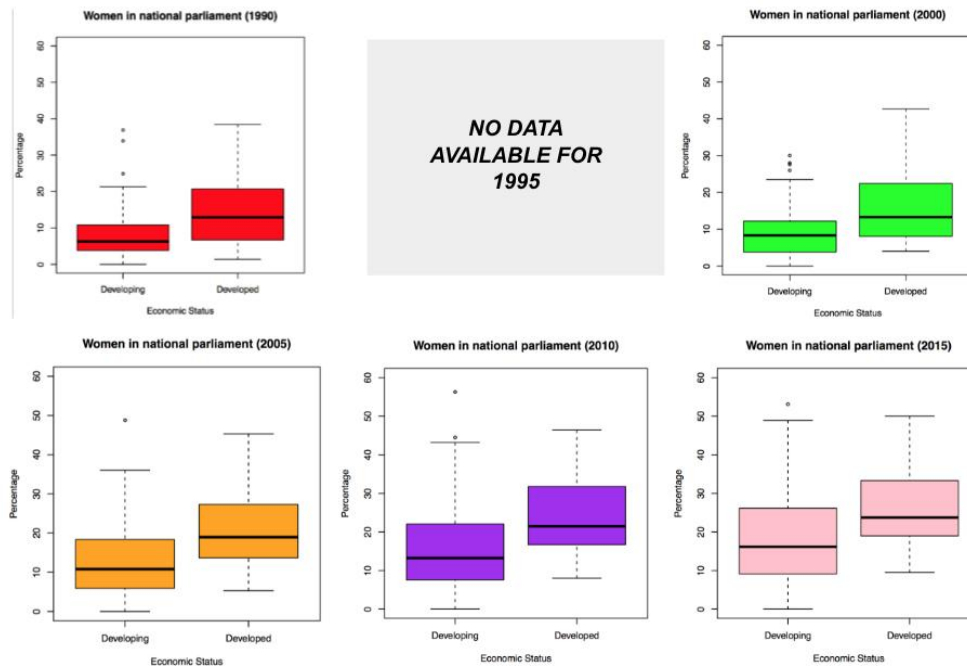
Figure 22: Proportion of seats held by women in national parliament in developing and developed countries

However, the data revealed more about the developed countries. Regarding women in parliament, the range was large on both sides, and overall developed countries have made much more progress than developing countries over the years. In 1990, there was a definite difference seen between developing and developed countries, although developed countries did have a huge range. However, over the years the developing countries have pretty much caught up with developed countries in some cases, although the overall average is slightly lower and there is a huge range. No data was available for the year 1995, but a clear trend can be seen from the data available.

7.1.4 Implications for evidence-based policymaking
The data for maternal mortality, girls in secondary education, and women in parliament was initially used to try to explain trends in developing countries. However, the data was found useful also to developed countries and how evidence-based policymaking could become more effective.

First of all, within every indicator there were a couple countries that were statistically outliers. These countries were the ones bringing down world average. These countries would have to be focused on more than others in the future.

Second, within the "developing country" category, there was a huge range. Some countries had proportion of seats in national parliament held by women that were equal to or greater than the proportion of most developed countries. Therefore the umbrella term "third world country" or "developing countries" no longer seemed to be a great method of approaching improvement of the world.

Third, developed countries have to work on their empowerment of women. Relative to the advances in health and education, women are not seeing proportionate involvement in government and politics. This societal problem is one that the developing country is falling behind on, and must focus on in the future.

Although the trends seen were not expected, the data has shown tangible results that policymakers can use as guidance in making more informed decisions.

7.2 Malnutrition in Central America and its Relationship to Key Health Conditions

In this case study of DV, we focused on Malnutrition, Incidence of Tuberculosis and the Maternal Mortality Ratio particularly in Central America. We are interested in exploring the potential correlation between malnutrition and key health conditions. To that end, we assessed how different countries' health conditions changed over time with the implementation of MDGs, and offer how health policy in Central America should be changed in the future. We focused on the Mexico/Central American Region of Developing Economies as defined by the World Economic Situation and Prospects of 2012.

7.2.1 Visualizations of health indicators in Mexico and Central American region
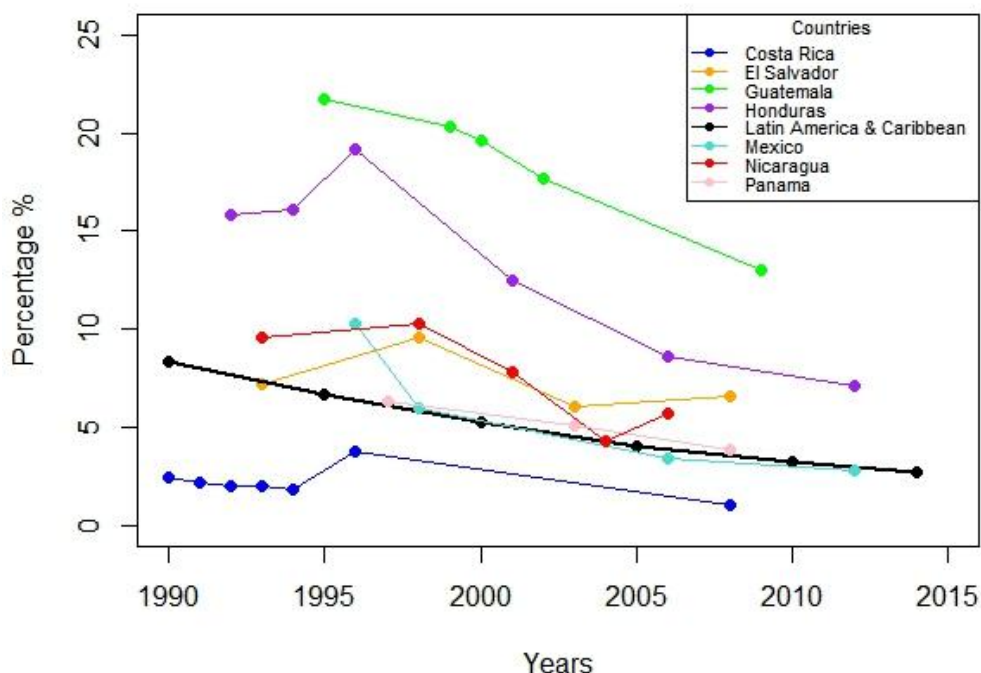
Figure 23: Percentage of underweight children under age 5 in Mexico and Central American Regions.

Figure 23 is a line plot that represents the Percentage of Underweight Children Under Age 5 of seven different countries: Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, and Panama. Underweight and Stunting are two indicators that the World Health Organization uses to assess malnutrition. We can see that Honduras, the purple line, has the highest drop in percentage, Costa Rica, the dark blue line, has the lowest percentages overall, and Guatemala, the green line, has the highest percentages overall. The black line, which represents the average percentages for the Latin America & Caribbean region, is only above the percentages for Costa Rica, and closely follows the pink line that represents Panama. This means that most of the countries represented in this line plot have percentages of Underweight children far worse than the average percentages of the Latin America & Caribbean region.

Prevalence of stunting, height for age (% of children under 5)
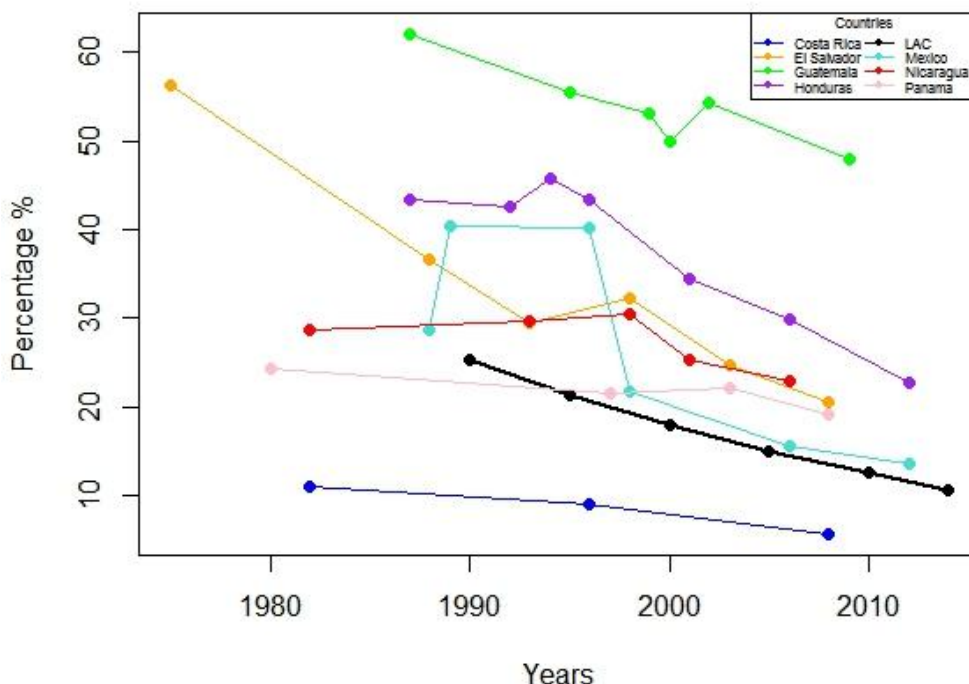
Figure 24: Prevalence of stunting, height for age of children under age 5 in Mexico and Central American Regions.

In Figure 24, the line plot represents the Prevalence of stunting, height for age of children under age 5 for the same countries. Looking at the whole graph, El Salvador has highest drop in percentage, but if we look at the data starting from 1990, Honduras has the highest drop in percentage. Again we see that Costa Rica has the lowest percentages overall and Guatemala has the highest percentages overall. This time, Costa Rica is the only country that is below the line that represents the Latin american & Caribbean region.

However, overall, all of the countries are on a decreasing trend. Mexico saw a fairly large increase beginning in 1990 when the other countries saw the beginning of a decreasing

trend. This may have been due to the Hurricane Diana that occurred in 1990 and the repercussions that the country faced.

Figure 25: Incidence of tuberculosis in Mexico and Central American Regions.

In Figure 25, the line plot represents the Incidence of Tuberculosis per 100,000 people for the same group of countries. Again, we see that Honduras had the highest drop in incidence, reflecting its highest drops in percentage of stunting and underweight children. The timing of when the drops occur seem to be around the year 1995. Additionally, we see that Costa Rica has the lowest incidence of tuberculosis. In this graph we can see that Mexico and Costa Rica have incidences of tuberculosis that are below the average Incidence of Tuberculosis for the Americas. As opposed to the line plots for Stunting and Underweight children where all the countries had decreasing trends, this line plot seems to have countries that have trends where the countries experience relapses and the incidences seem to get worse over time.

Maternal mortality ratio (modeled estimate, per 100,000 live births)

Years
Mexico/Central American Region of Developing Economies
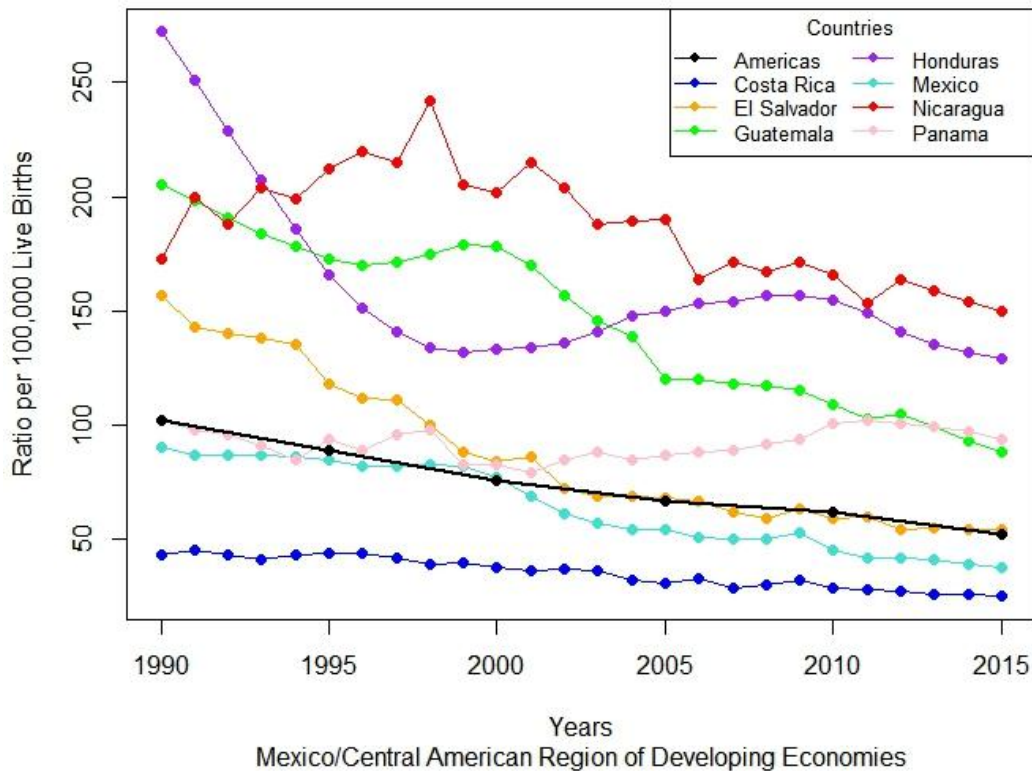
Figure 26: Maternal Mortality in Mexico and Central American Regions.

In Figure 26, the line plot portrays the Maternal Mortality Ratio per 100,000 live births in the same countries. We see that Honduras has the steepest drop in maternal mortality ratio from 1990 to 2000. Interestingly in Honduras, the drop in maternal mortality is before the drop in incidence of tuberculosis by approximately 10 years. Again, we see that Costa Rica has the lowest percentages. Both Mexico and Costa Rica are countries that have ratios that are below the average ratios for the Americas region. Overall, Nicaragua has the highest percentages. Panama seems to experience nearly no change in their ratios from 1990 to 2015.

7.2.2 Implications for policymakers

It seems there is no direct correlation between malnutrition and key health conditions such as incidence of tuberculosis and maternal mortality ratio, because the DVs in this section did not factor into the potential effect of time-lag between a potential cause and effect. We discovered interesting trends that were apparent and, for the most part, consistent in each of the data visualizations.

First of all, Costa Rica consistently had the lowest percentages, incidences, and ratios of negative health conditions. All of the health indicators, except for Percentage of Underweight Children had a steady decreasing trend. This may be due to the fact that Costa Rica is largely regarded as having the most stable and most democratic government among the Central American countries. This type of government allowed for the people's voices to be heard and for a universal health care system to be established and then

reformed in the 1990s with a larger emphasis on expanding coverage. Additionally, Costa Rica has a policy that focuses on human development and therefore the health of its population.

Additionally, Honduras experienced a reform in its health system beginning in 1990, which may explain the steep drop that is shown in each data visualization. The reform aimed for a more progressive integration of the public insurance of the country, and that the population has access to timely and quality health services.

Looking at both Costa Rica and Honduras, it seems that health care systems that focus on spreading coverage and providing quality basic health services through public insurance seem to work and help improve the health of the population. Policymakers could research further into these two countries' health systems and see why their reforms worked and use them as examples for other nations.

Countries like Guatemala, which consistently had the highest prevalence in regards to malnutrition, and was still fairly high in incidences of tuberculosis and maternal mortality ratio, have health systems with high levels of private expenditure and unequal access to healthcare facilities. Nicaragua also has an issue with rural regions having less access to healthcare facilities, and thus the population in rural regions have worse health. Therefore, this is an indicator that unequal access to health care facilities need to be eliminated.

When we look at the data visualizations as a whole, we notice that some countries are consistently in worse health conditions compared to the other countries, and also typically when one health indicator is bad, the rest are bad as well. This is an implication that countries such as Nicaragua and Guatemala, the two countries that seem to be faring the worst out of this group of countries, need to be focused on to protect the health of the population. We recommend UN health organizations, medical NGOs and developed countries in North America provide due attention and viable resources to help Nicaragua and Guatemala to improve their public health infrastructure. Communicable disease like TB knows no borders.

7.3 Malnutrition in North Korea and Evidence-based Policy Implications

In this case study, we focus on public health issues in the Democratic People's Republic of Korea (DPRK, known as North Korea), a country known for its totalitarian dictatorship. DPRK has a land area of approximately 123,138, 80% of which is mountains and uplands. The northeastern part of the country is made up of high mountains, while the southwest has sea-level land. The mountainous structure, coupled with the long and cold winters, can present challenges to citizens of the DPRK, especially those living in the northeastern provinces. In our visualizations, we take into account the unique topographic structure of the DPRK. As a result, the reader will often see data presented on a map of the DPRK.
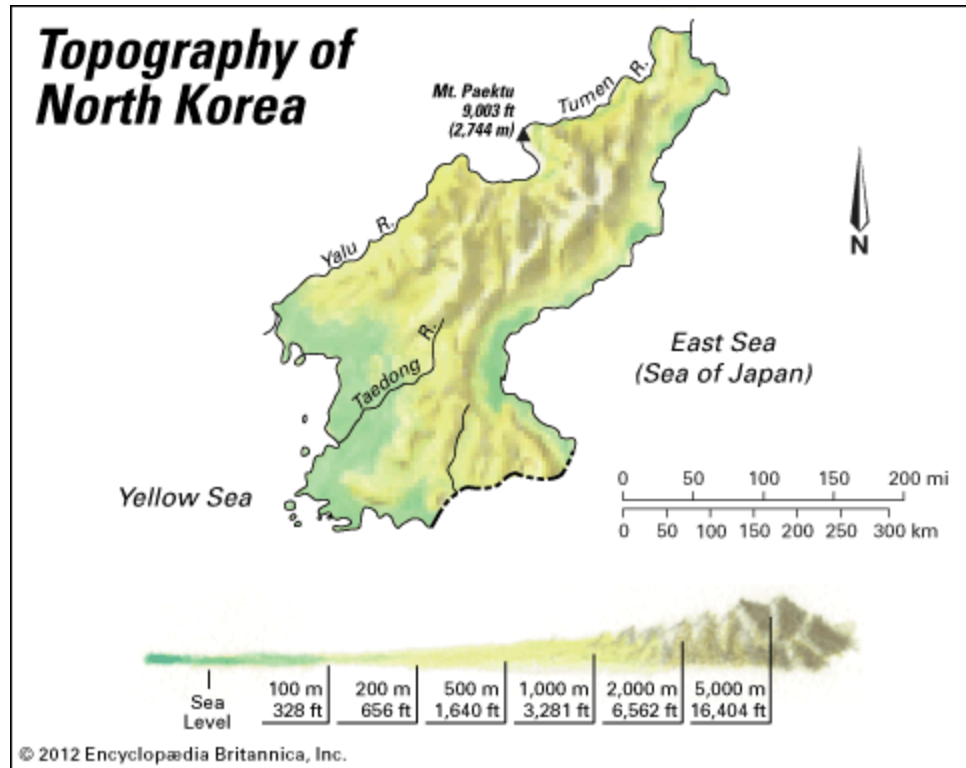
Figure 27: Topography of DPRK. Source is Encyclopedia Britannica, Inc.

7.3.1 Map visualization of maternal mortality rate

Maternal Mortality Rate (MMR) is a health metric often used by the World Bank, WHO, and other agencies to make international comparison of mothers' health. We used the mapping method to delve into the health status of mothers, creating DVs to illustrate MMR and the percentage of maternal deaths at hospitals.

In order to create the DVs in this section, we make use of the data from Table 18 in the 2008 Census. We also used the shape file of the DPRK border from the Database of Global Administrative Boundaries.

MMR by Province:
According to the World Bank, MMR is the number of women who die from pregnancy-related causes per 100,000 live births. MMR is calculated using the formula:
(number of maternal deaths/ number of live births)*100,000.

In Figure 28, MMR is color-coded from low to high, and displayed by province on a map of the DPRK. Ryanggang, North Hamgyong and North Phyonggan have the highest MMR, and Pyongyang has the lowest MMR. We see that Northern provinces tend to have higher MMR, while Pyongyang and North Hwanghae, which are geographically close to each other, have lower MMR.

Percentage of Deaths at Hospital by Province:
For each province, the percentage of maternal deaths at hospital is calculated using the formula:

(Number of maternal deaths at hospital/ Number of maternal deaths)*100

In Figure 29, percentage of maternal deaths at hospital is color-coded from low to high, and displayed by province on a map of the DPRK. Pyongyang has the highest percentage, while Ryanggang, South Hamgyong and Kangwon have the lowest percentages. A possible explanation is that the capital has better access to hospital facilities; therefore, deaths occur at the hospital, as opposed to at home or elsewhere. The three aforementioned provinces, which have the lowest percentages of deaths at hospital, are located in mountainous areas. Therefore, citizens of those provinces might have difficulty accessing the hospital.

Maternal Mortality Rate by Province
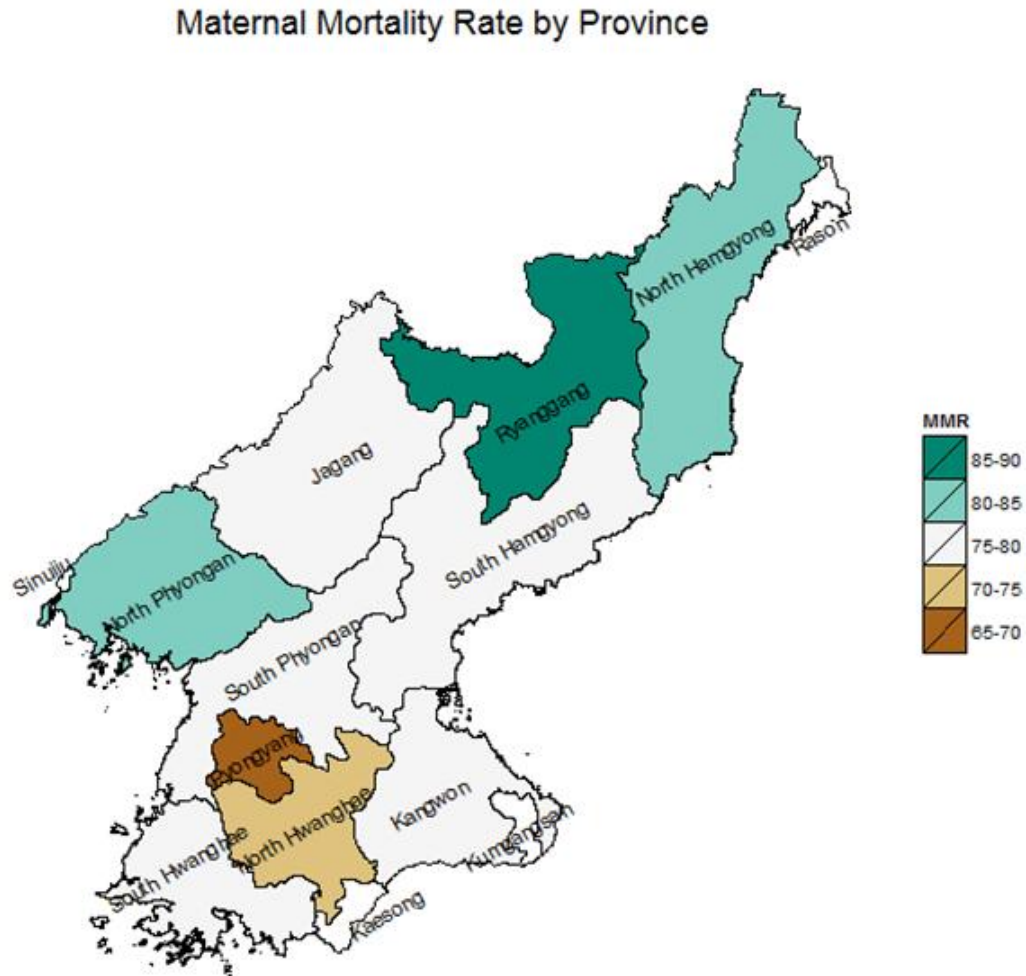
Figure 28: Maternal Mortality Rate by Province in DPRK

Percentage Deaths at Hospital by Province
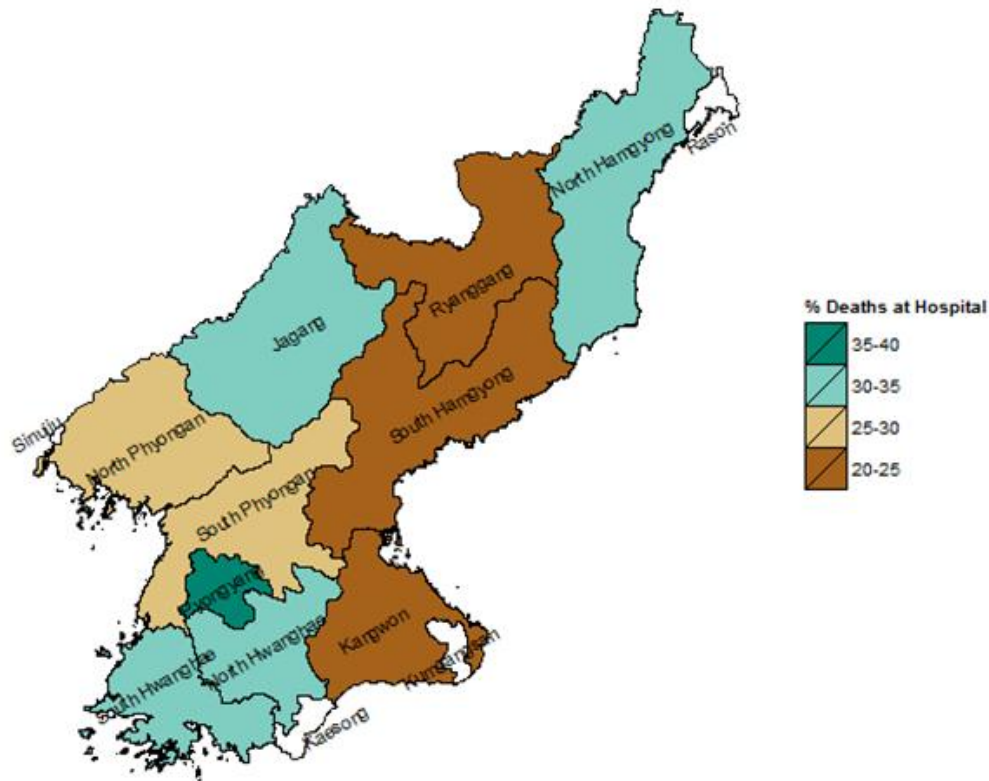
Figure 29: Percentage of Deaths at Hospital by Province in DPRK

7.3.2 Map visualization of malnutrition

In Figures 30 and 31, we focused on the prevalence of global acute and global chronic malnutrition by provinces in the DPRK. Data were obtained from tables 6.2 and 6.3 in NNS 2012.

In each map, the intensity of the color represents the prevalence of malnutrition. Darker color signals higher prevalence of malnutrition. For both acute and chronic malnutrition, Ryanggang has the highest prevalence while Pyongyang has the lowest. Interestingly, as the provinces get further away from Pyongyang, malnutrition seems to increase in intensity. We observe that the provinces that suffer from higher prevalence of malnutrition, such as Ryanggang, Jagang, and Kangwon, are mountainous provinces. On the contrary, provinces with lower prevalence such as Pyongyang, South Hwanghae, and South Phyongan enjoy a sea-level structure.

Figure 30: Prevalence of Global Acute Malnutrition in Children by Province in DPRK

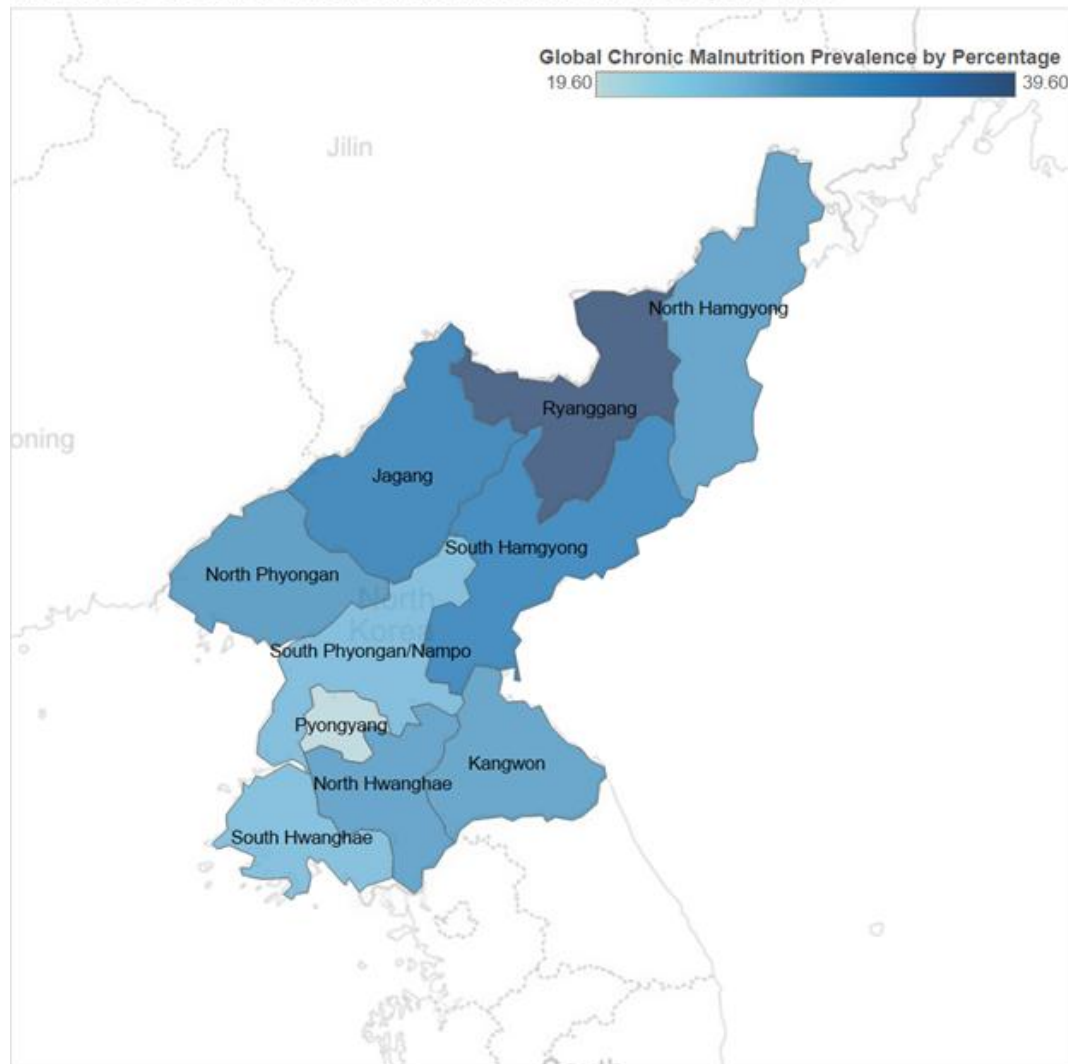Prevalence of Global Chronic Malnutrition in Children by Province

Figure 31: Prevalence of Global Chronic Malnutrition in Children by Province in DPRK

7.3.3 Implications for policymakers

Throughout the visualizations, a trend consistently emerges: citizens of Pyongyang enjoy the best health status in the nation, while Northern provinces such as Ryanggang and Jagang display the worst health conditions. Policies that aim at equal development in the DPRK should take into account this trend, investing heavily in these Northern provinces. We emphasize the importance of the DPRK's natural conditions, such as its topographic structure, climate, and natural hazards. Provinces in the mountainous areas seem to struggle the most with health issues such as high maternal deaths, high prevalence of children's malnutrition, and high prevalence of TB and malaria. At the same time, people from all over the country migrate to Pyongyang, perhaps in search of better living conditions (Nguyen et al., 2015). These specifics will help inform designing development policies in the DPRK.

7.4 Interactive DVs of Public Health Issues

7.4.1 Interactive histogram and interactive map of hunger and access to sanitation facilities

Hunger was at the forefront of world leaders' thoughts when they came together to draft the Millennium Development Goals in 2000. Fifteen years later, the Millennium Development Goals 2015 Report states   that the proportion of undernourished people has been almost halved; however, progress varied widely across different regions. Furthermore, people who have managed to escape poverty might easily fall back into it, due to economic shocks and living conditions. In this case study, we strive to answer two research questions using data visualization: 1) what regions in the world are falling behind in hunger reduction, and 2) what is the relationship between hunger reduction and the state of sanitation facilities.

We obtained the data from the United Nations' Millennium Development Goals Indicators database. Two datasets were downloaded: Percentage of Population Undernourished (under Target 1C) and Total Proportion of the Population Using Improved Sanitation Facilities (under Target 7C). We cleaned the .csv data files to remove information unnecessary for visualization such as data series name and foot notes. Data on the population undernourished and the proportion using improved sanitation facilities were unaltered. We combined these two data sets with data on longitudes and latitudes of countries. This data set was obtained from Dataset Publishing Language. Data combination was done using Excel.

There are two components in this DV: an interactive histogram and an interactive map. The histogram is a quick visualization of the status of hunger in the world. Clicking the "Play" button in the histogram tab will start an animation of the histograms of population undernourished from 1991 to 2015.

The interactive world map provides viewers with a comprehensive picture of the situations in all nations. Two variables are displayed on this world map: the percentage of the population that is undernourished, and the proportion of the population that is not using improved sanitation facilities. The countries are filled with colors depending on their levels of undernourished population. The circles on the map display the percentage of the population that is not using improved sanitation facilities. Bigger circles represent higher percentages of population not using improved sanitation facilities. The world map also provides an easy way to compare the situations in different countries or regions. Viewers can zoom in the map to look into countries or regions of interest, whereas the popup windows (upon clicking on the map) provide additional information about the percentage of population undernourished, or the proportion not using sanitation facilities. Furthermore, the "year" slider allows viewers to view changes over time.

7.4.2 Implications for policymakers

From this histogram, we observe that in general, the undernourished population has decreased over the period 1991-2015. However, in 2015, there were still countries whose undernourished population falls between 40% and 60%. This is an alarmingly high number and effort needs to made to improve the situation in these countries. Furthermore, we observe from the world map that most of the countries with high undernourished population are in Africa and Western Asia. Policymakers could invest resources in Africa to improve the issue of undernourishment.

When observed over time, some countries fluctuate in their undernourished population. Policymakers might wish to investigate the reasons for the fluctuation and address the issues to ensure sustainable development.

Finally, we observe a correlation between the population not using improved sanitation facilities and the population undernourished. On the world map, this correlation can be observed clearly, since countries with darker colors also display bigger circles. Policies that aim at reducing world hunger could take advantage of this correlation: hunger could be reduced by simultaneously addressing the issue of improved sanitation facilities.
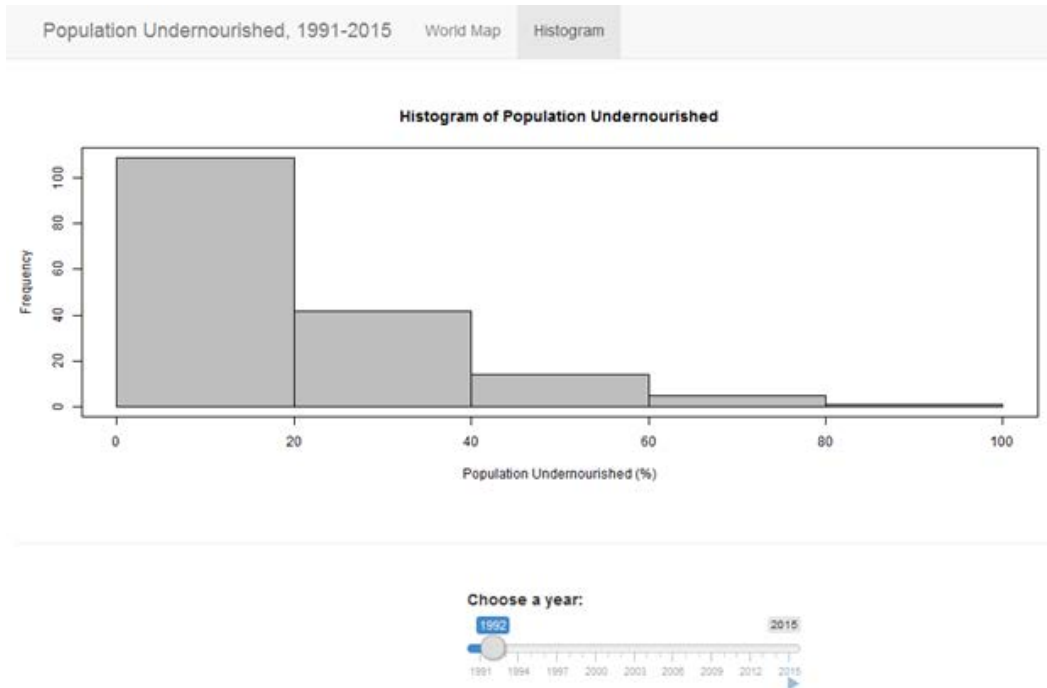
Figure 32: Snapshot of interactive histogram, showing population undernourished, 1991-2015
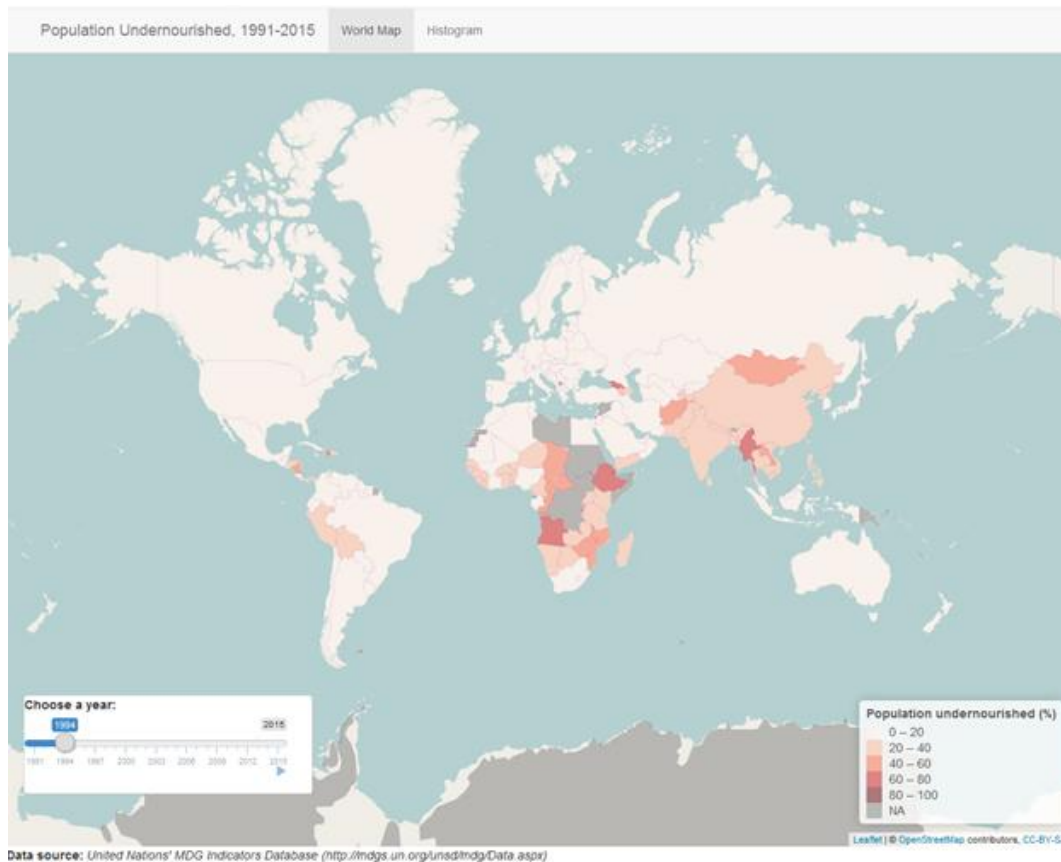
Figure 33: Snapshot of Interactive world map showing population undernourished, 1991-2015

8. Conclusions

Data from the United Nations' Millennium Development Goals Indicators, the World Bank's Open Data, and others, provide abundant information on the major policy issues in developing countries. By utilizing multiple data tables from these sources, we developed a series of static and interactive visualizations that are informative to policymakers and the public.

We created data visualizations to aid the United Nations and non-governmental agencies in making evidence-driven decisions about development programs. However, we caution that our visualizations display correlation rather than causation. It is also important to acknowledge the differences in culture, history, topography, politics, and economic situations in developing countries. Understanding of the specifics of a developing country is essential before any policy is implemented.

Future research can build on our work in two major ways. First, nonresponse and incomplete data prove a challenging issue. Many countries and regions are not represented in several data sets, and some countries and regions only have data available in recent years. As a result, our understanding of these countries is lacking, and we could not paint a complete picture of the health, social, and economic conditions of the world. It is worthwhile for future research agendas to investigate this issue further and strive to obtain more complete data. Second, even though EBP can result in tremendous
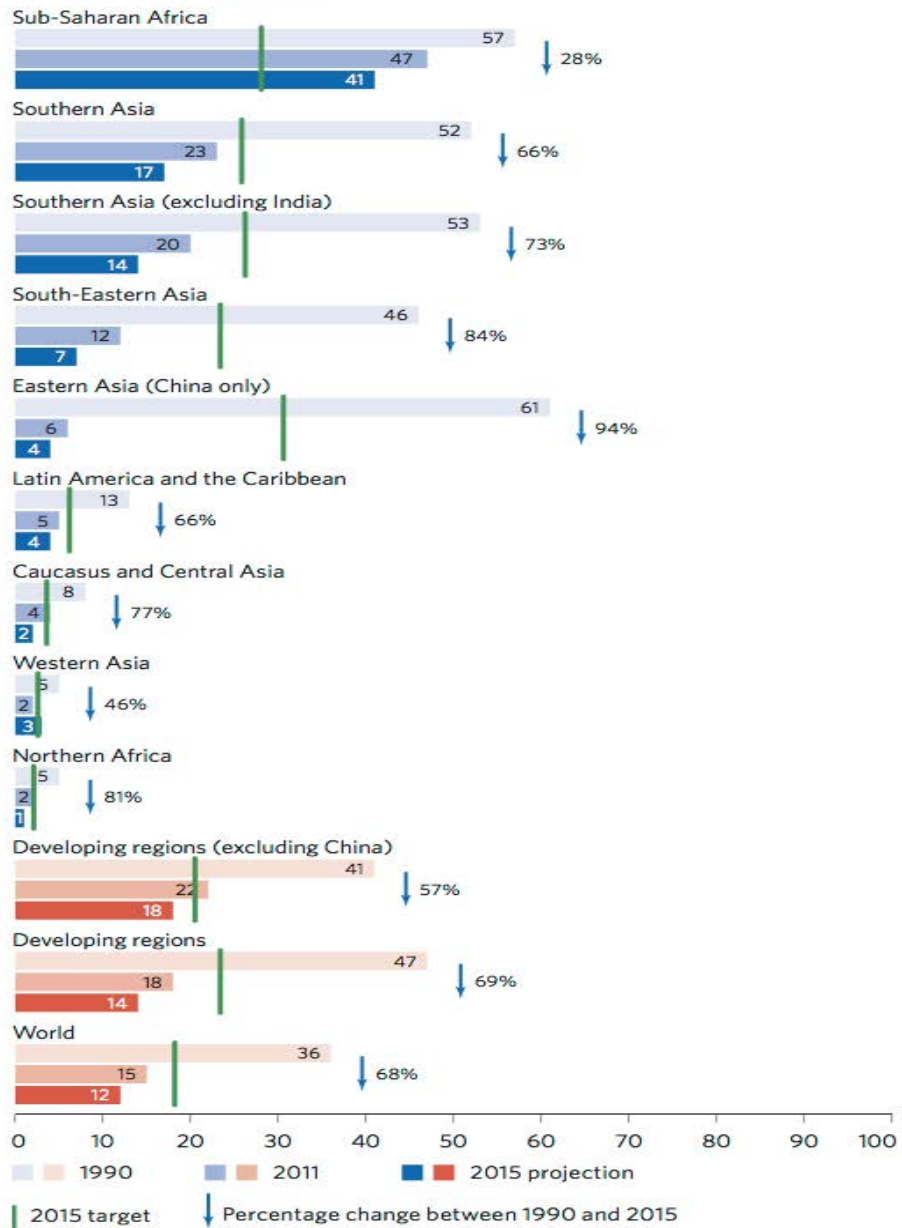
improvements in developing countries, we face a lot of challenges in the implementation of EBP agendas. Natural disasters, political instability, and conflicts prove predicaments to the success of EBP. Future research may choose to investigate this issue and design feasibility studies of EBP in developing regions.

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Few, S. (2011, December). Benefitting InfoVis with Visual Difficulties? Provocation Without a Cause". Visual Business Intelligence Newsletter Perceptual Edge. Retrieved from http://www.perceptualedge.com/articles/visual_business_intelligence/visual_difficulties.pdf

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Appendix[5]

Proportion of people living on less than $1.25 a day, 1990, 2011 and 2015 (percentage)
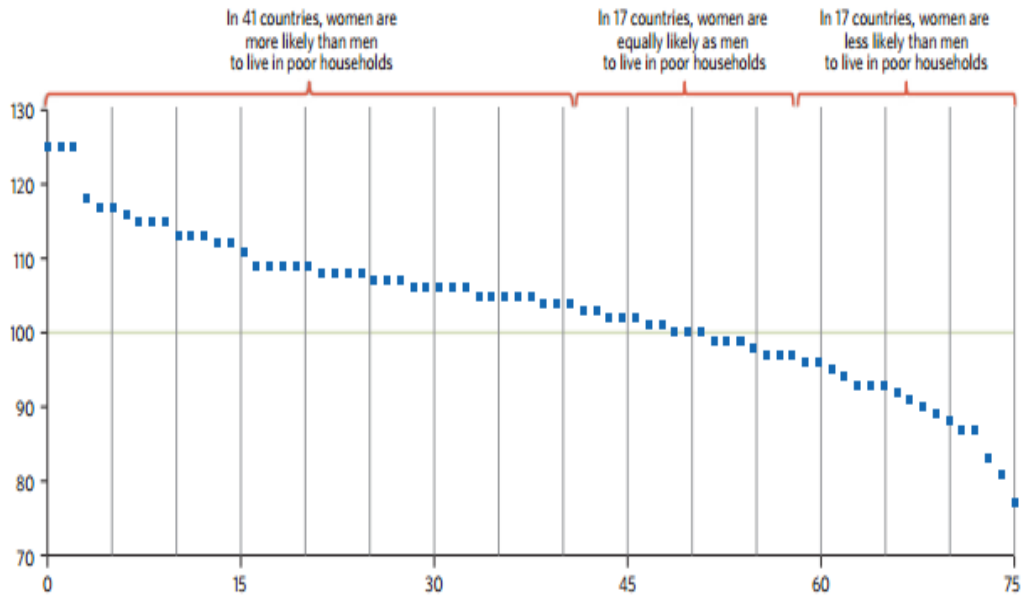
Sub-Saharan Africa
57
47
41
↓ 28%

Southern Asia
52
23
17
↓ 66%

Southern Asia (excluding India)
53
20
14
↓ 73%

South-Eastern Asia
46
12
7
↓ 84%

Eastern Asia (China only)
61
6
4
↓ 94%

Latin America and the Caribbean
13
5
4
↓ 66%

Caucasus and Central Asia
8
4
2
↓ 77%

Western Asia
5
2
3
↓ 46%

Northern Africa
5
2
1
↓ 81%

Developing regions (excluding China)
41
22
18
↓ 57%

Developing regions
47
18
14
↓ 69%

World
36
15
12
↓ 68%

0 10 20 30 40 50 60 70 80 90 100

☐ 1990   ☐ 2011   ■ 2015 projection

| 2015 target   ↓ Percentage change between 1990 and 2015

Note: Sufficient country data are not available for Oceania.

Figure 1: Proportion of people living on less than $1.25 a day. Figure from MDG Report 2015, United Nations

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[5] Figures included in Appendix are extracted from the Millennium Development Goals Report (UN, 2015).

Ratio of women to men of working age (20 to 59) in the lowest wealth quintile of all households, selected developing countries, 2000−2013

In 41 countries, women are more likely than men to live in poor households

In 17 countries, women are equally likely as men to live in poor households

In 17 countries, women are less likely than men to live in poor households

Notes: This indicator is weighted by the ratio of females to males aged 20–59 in all households to reflect the fact that women may be overrepresented in the entire population. It uses the wealth asset index in the Demographic and Health Surveys and Multiple Indicator Cluster Surveys as a proxy measure for poverty. Values above 103 indicate that women are overrepresented in the lowest wealth quintile while values below 97 indicate that men are overrepresented in the lowest wealth quintile. Values between 97 and 103 indicate parity.

Figure 2: Ratio of women to men of working age in the lowest wealth quintile. Figure from MDG Report 2015, United Nations

**Proportion of undernourished people,
1990–1992 and 2014–2016 (percentage)**
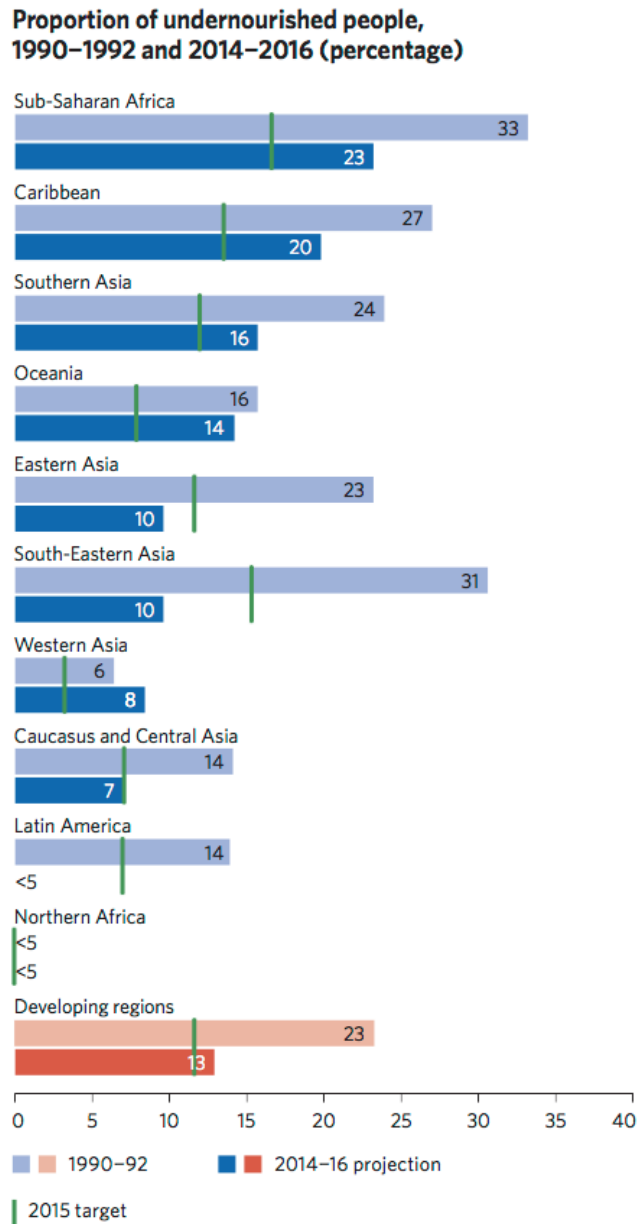
Figure 3: Proportion of undernourished people. Figure from MDG Report 2015, United Nations

Figure 4: Distribution of working-age women and men. Figure from MDG Report 2015, United Nations

Figure 5: Ratio of under-five mortality rate for children. Figure from MDG Report 2015, United Nations

Estimated child deaths due to measles (thousands) and proportion of children in the appropriate age group who received at least one dose of measles-containing vaccine (percentage), 1990–2013
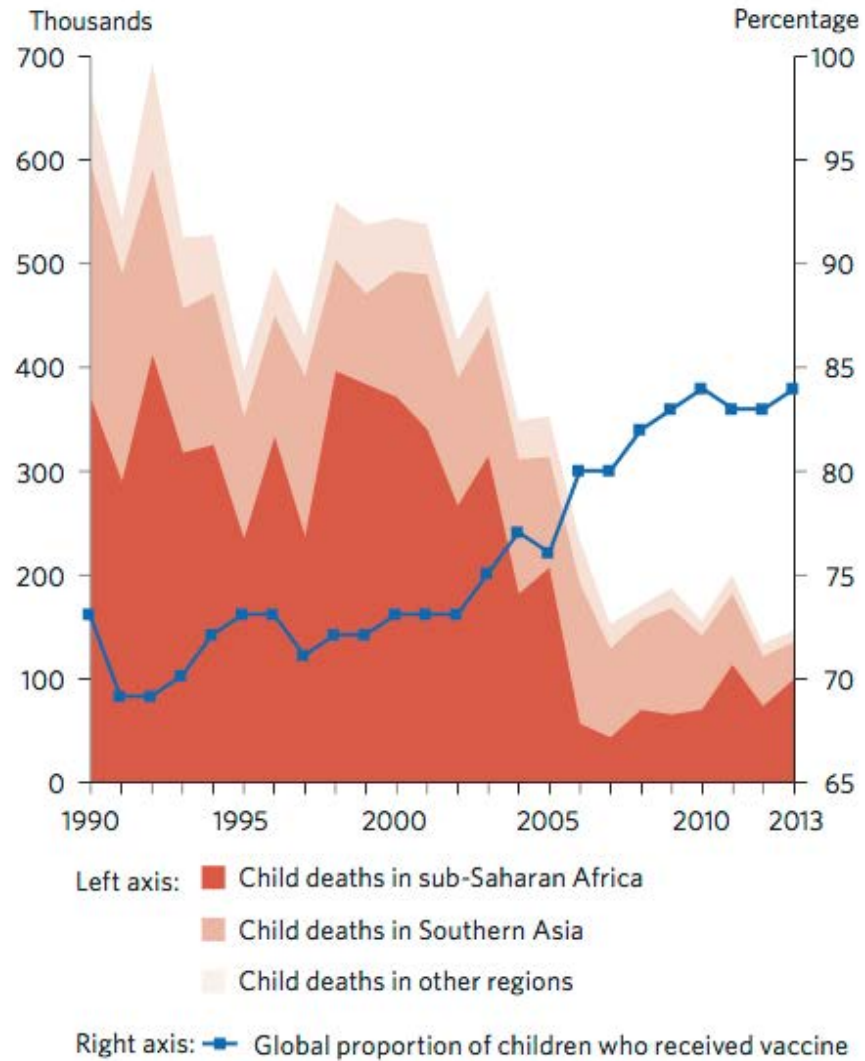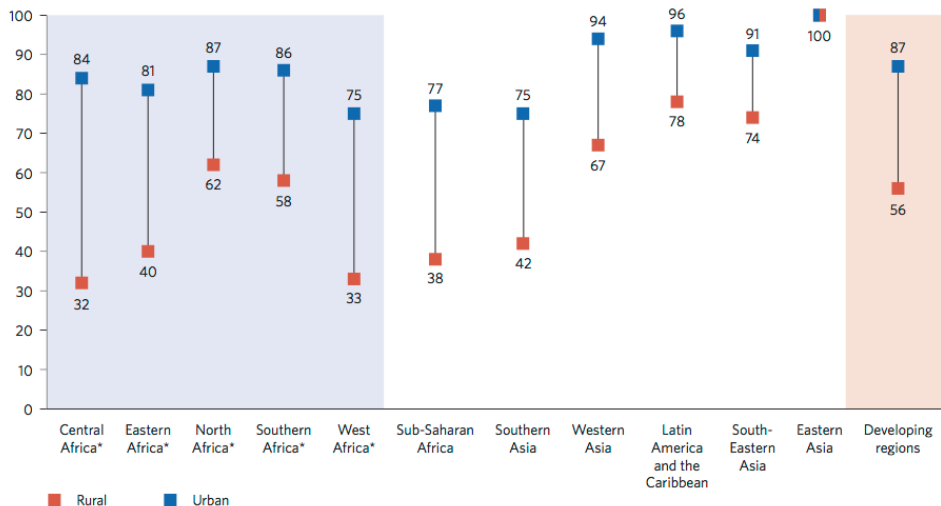
Figure 6: Estimated child deaths due to measles (thousands). Figure from MDG Report 2015, United Nations

Inequalities in access to maternal health care persist across most regions

Proportion of deliveries attended by skilled health personnel in rural and urban areas, 2010–2014 (percentage)

■ Rural   ■ Urban

*The composition of the subregions of Africa is shown on page 71.

Figure 7: Inequalities in access to maternal health care. Figure from MDG Report 2015, United Nations

Proportion of women aged 15–49 attended four or more times by any provider during pregnancy, 1990, 2000 and 2014 (percentage)
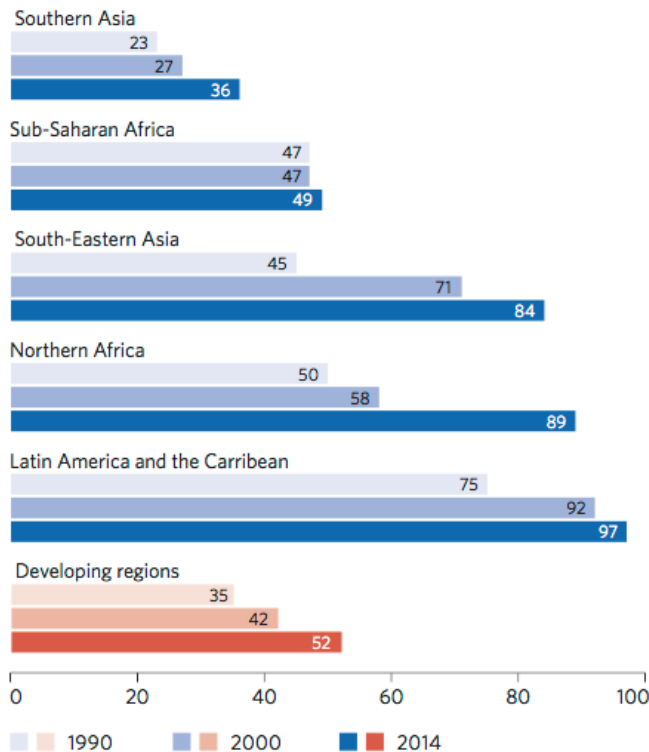

1990   2000   2014

Figure 8: Proportion of women attended four or more appointments. Figure from MDG Report 2015, United Nations

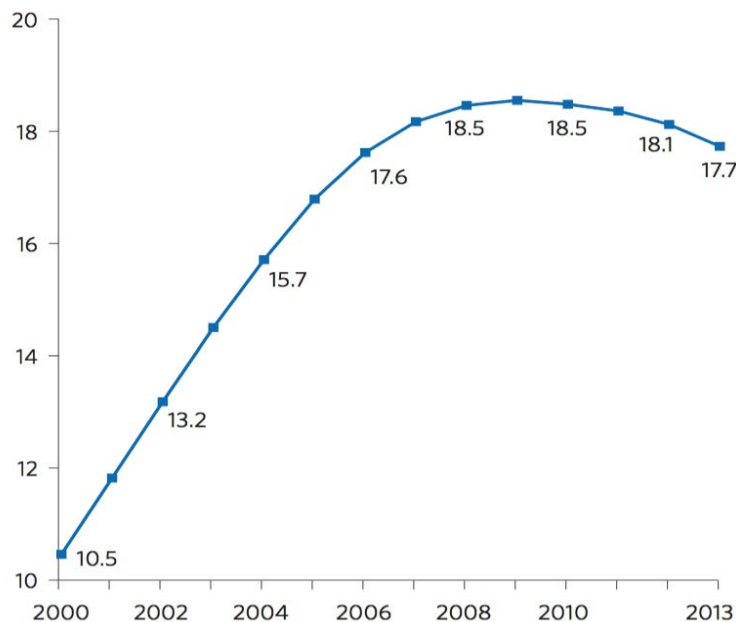**Estimated number of AIDS-related orphans worldwide, 2000–2013 (millions)**

Figure 9: Estimated number of AIDS-related orphans worldwide. Figure from MDG Report 2015, United Nations
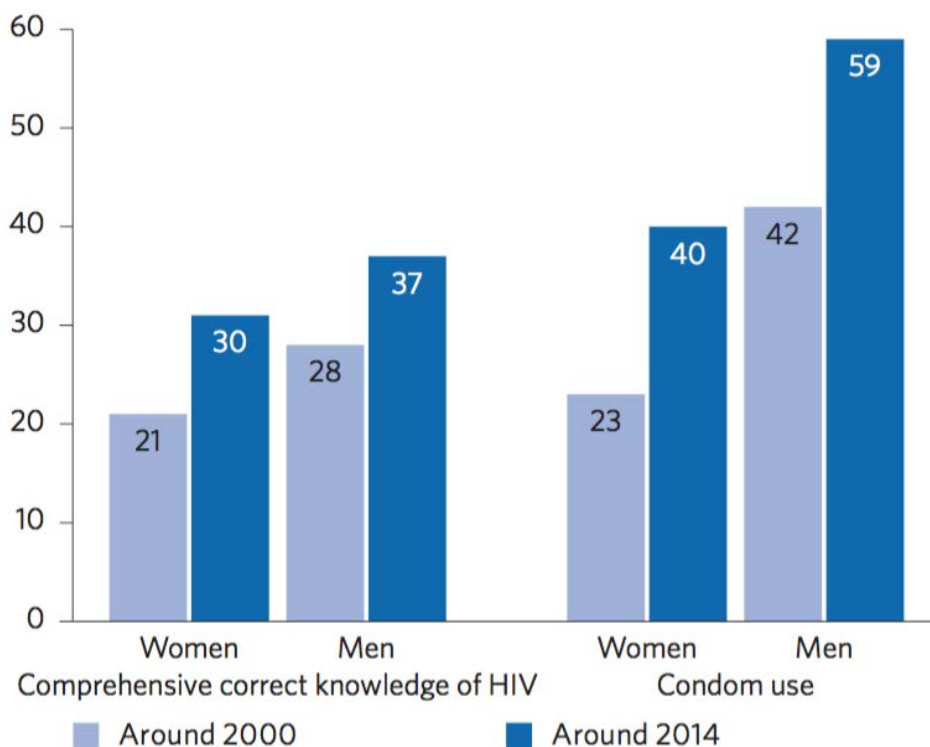

Figure 10: Proportion of women and men aged 15¬24 in sub-Saharan Africa with comprehensive correct knowledge of HIV transmission and reporting condom use at last higher-risk sex, around 2000 and 2014 (percentage). Figure from MDG Report 2015, United Nations

Proportion of children under age five sleeping under insecticide-treated mosquito nets for selected countries in sub-Saharan Africa, around 2001 and 2013 (percentage)
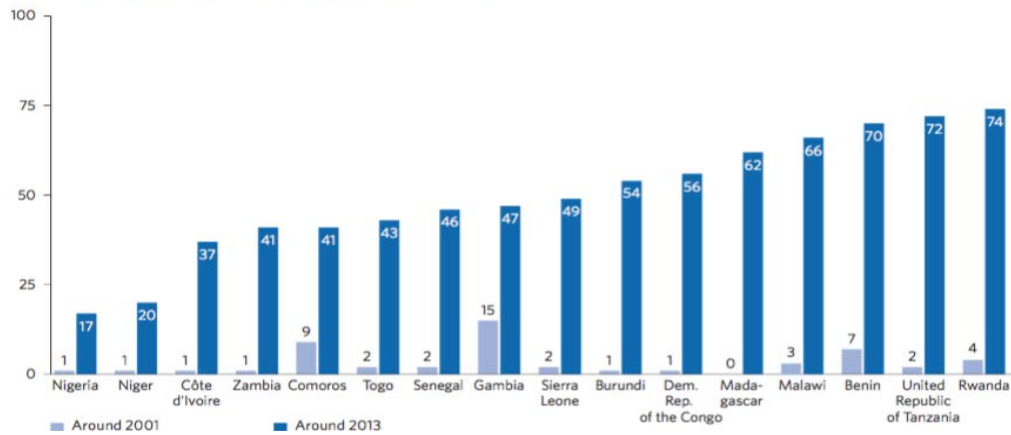
Figure 11: Children under five sleeping under insecticide-treated mosquito nets (Proportion). Figure from MDG Report 2015, United Nations

Estimated change in malaria incidence rate (cases per 1,000 population at risk) and malaria mortality rate (deaths per 100,000 persons at risk), 2000−2015
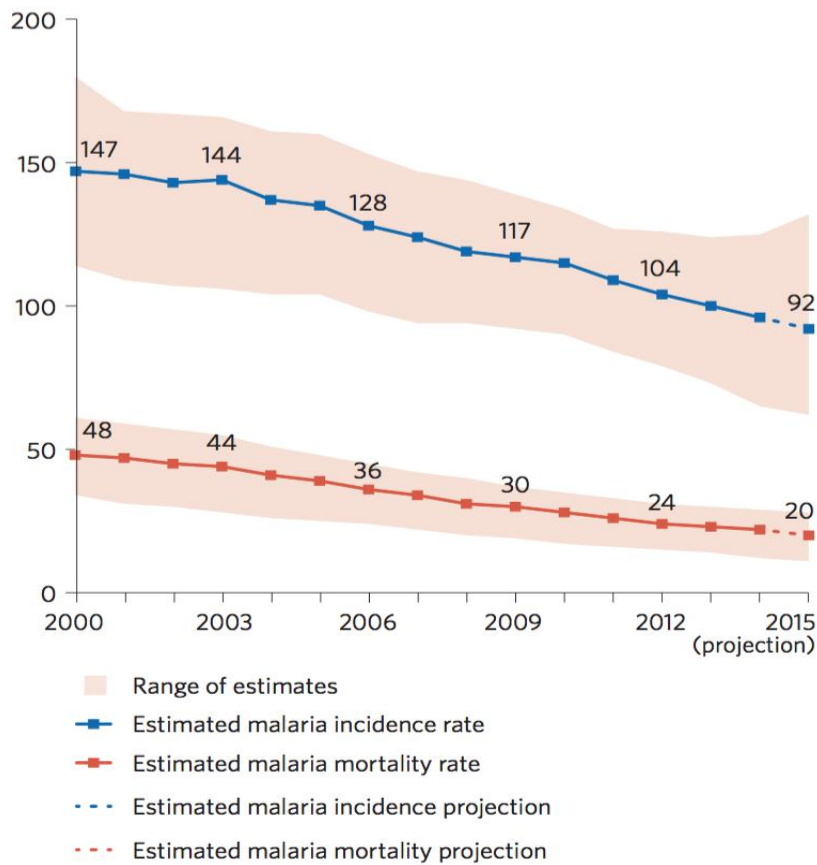
Figure 12: Change in malaria incidence rate and mortality rate. Figure from MDG Report 2015, United Nations
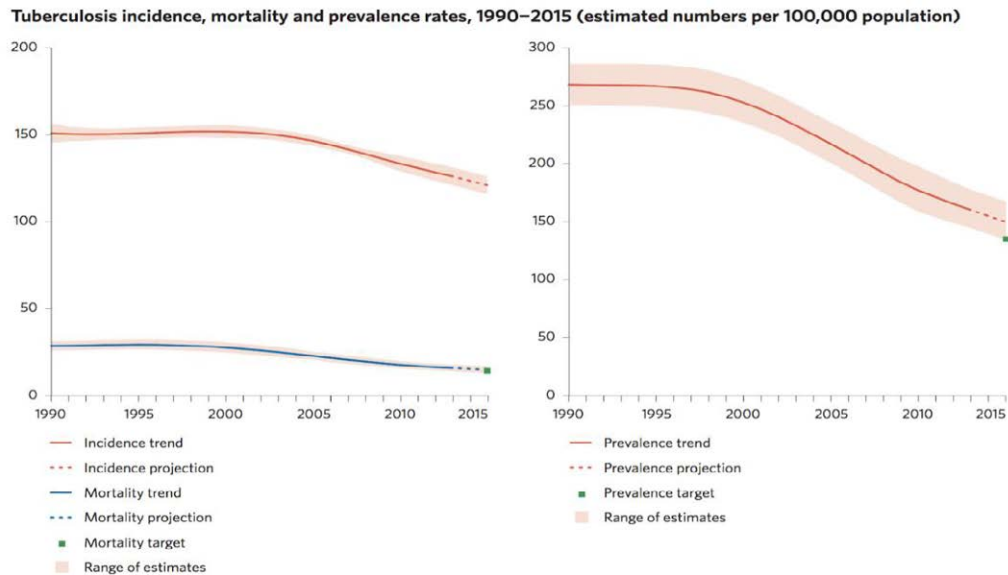
Tuberculosis incidence, mortality and prevalence rates, 1990–2015 (estimated numbers per 100,000 population)

Incidence trend
Incidence projection
Mortality trend
Mortality projection
Mortality target
Range of estimates

Prevalence trend
Prevalence projection
Prevalence target
Range of estimates

Note: In both panels, the green box marks the Stop TB target of a 50 per cent reduction by 2015 compared with 1990. Incidence rate refers to new cases per 100,000 population including people who are HIV-positive. Mortality rate refers to deaths due to tuberculosis per 100,000 population excluding people who are HIV-positive.

Figure 13: Tuberculosis incidence, mortality, and prevalence rates. Figure from MDG Report 2015, United Nations

Tuberculosis treatment success rate, developed and developing regions, 1995–2012 (percentage)
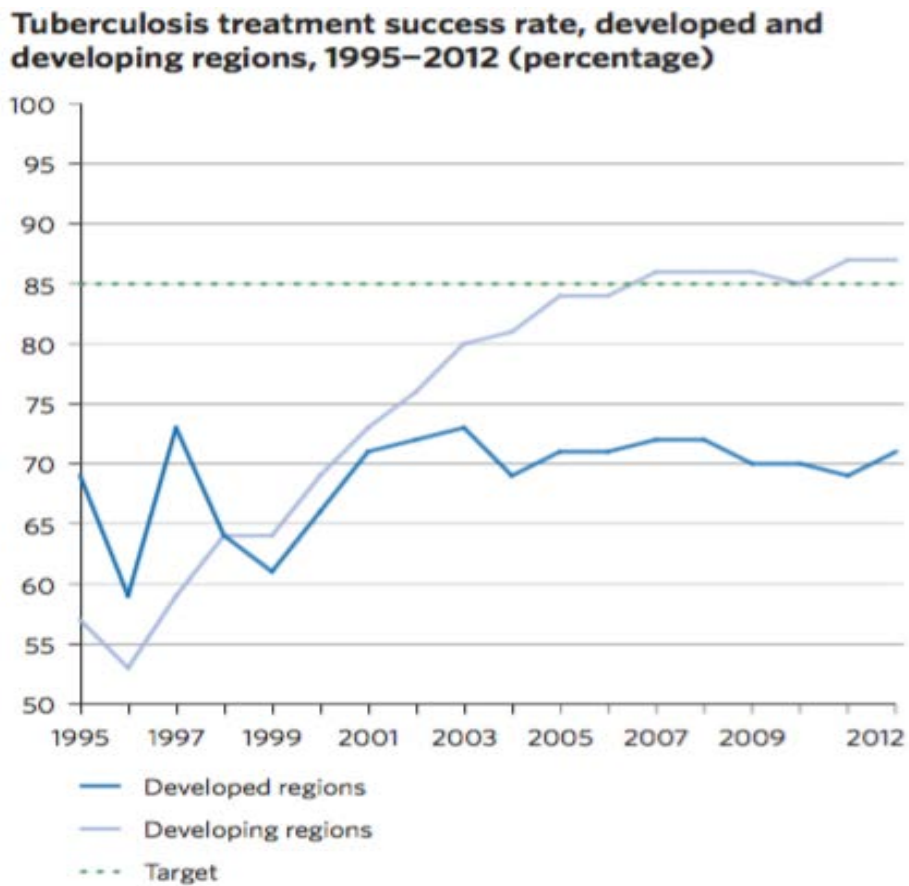

Developed regions
Developing regions
Target

Figure 14: Tuberculosis treatment success rate in developed and developing regions. Figure from MDG Report 2015, United Nations

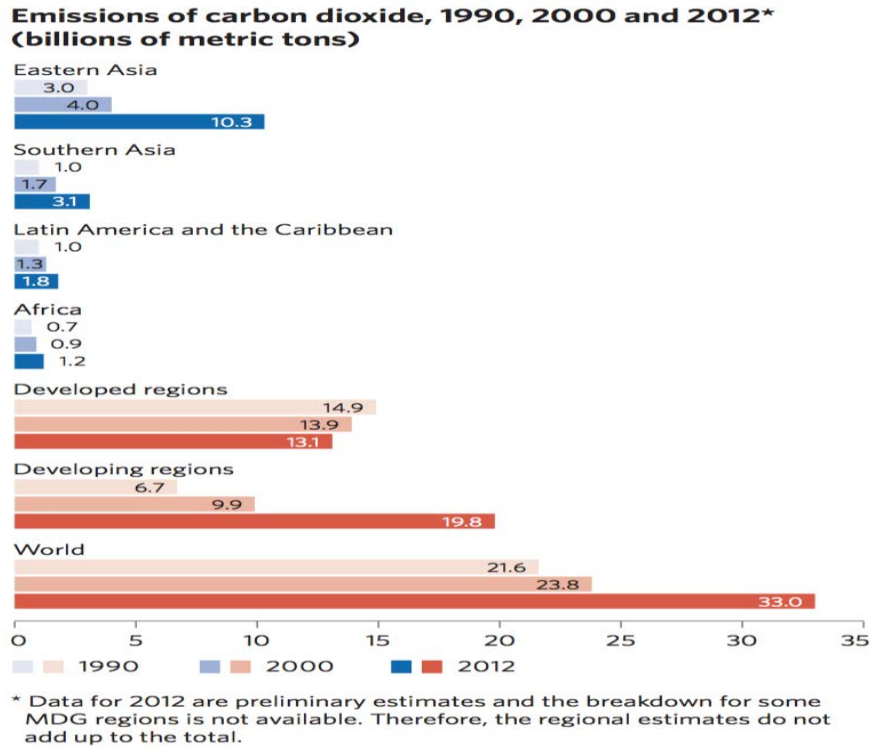**Emissions of carbon dioxide, 1990, 2000 and 2012***
(billions of metric tons)

Eastern Asia
3.0
4.0
10.3

Southern Asia
1.0
1.7
3.1

Latin America and the Caribbean
1.0
1.3
1.8

Africa
0.7
0.9
1.2

Developed regions
14.9
13.9
13.1

Developing regions
6.7
9.9
19.8

World
21.6
23.8
33.0

0   5   10   15   20   25   30   35

1990   2000   2012

* Data for 2012 are preliminary estimates and the breakdown for some
MDG regions is not available. Therefore, the regional estimates do not
add up to the total.

Figure 15: Emissions of Carbon Dioxide. Figure from MDG Report 2015, United Nations

Millions   Percentage

Left axis: fish landings (catch that is brought ashore)
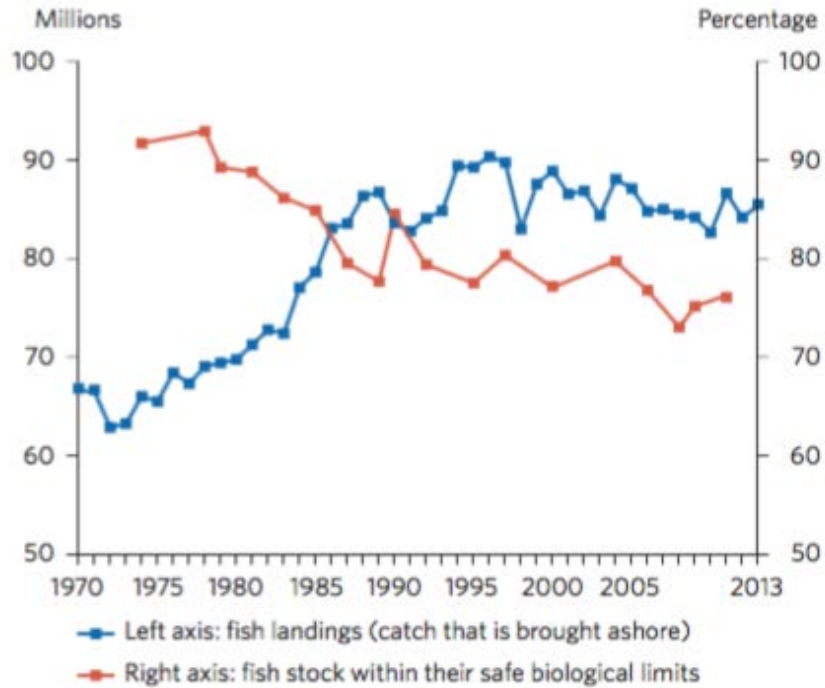Right axis: fish stock within their safe biological limits

Figure 16: Proportion of fish stocks within their safe biological limits and fish landings.
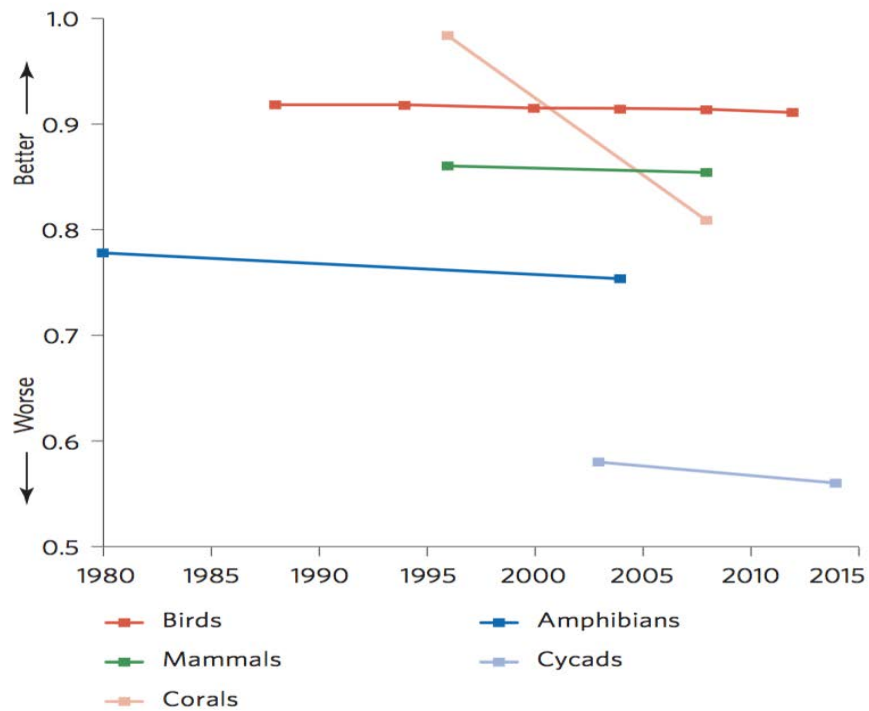Figure from MDG Report 2015, United Nations

Figure 17: IUCN Red List Index of species survival. Figure from MDG Report 2015, United Nations
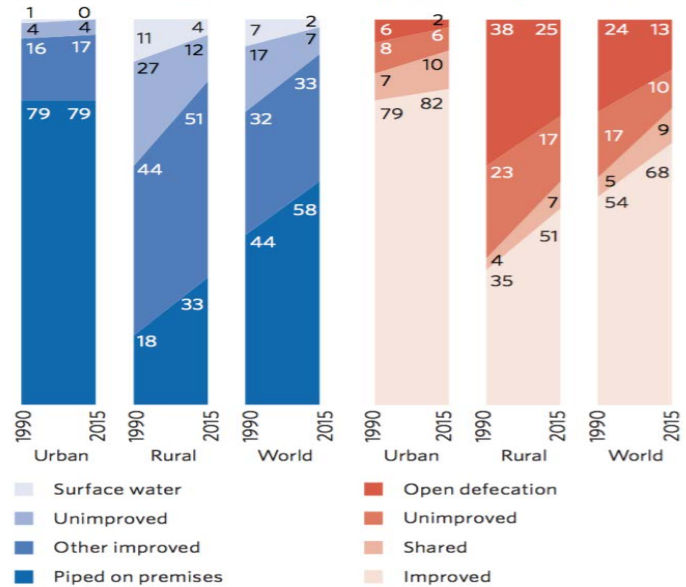

Figure 18: Proportion of population using improved and unimproved drinking water sources and sanitation facilities. Figure from MDG Report 2015, United Nations