Transnational wealth-related health inequality measurement

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\textbf{ABSTRACT}

The study of international differences in wealth-related health inequalities has traditionally consisted of country-by-country comparisons using own-country relative measures of socioeconomic status, which effectively ignores absolute differences in both wealth and health that can differ between and within countries. To address these limitations, we propose an alternative approach: that of constructing a transnational measure of wealth-related health inequality. To illustrate the limitations of the country-by-country approach, we simulate the impact of changes in wealth and health inequalities both between and within countries on cross-country measures of health inequality and find at least five errors that may arise using country-by-country methods. We then empirically demonstrate the transnational approach to wealth-related health inequalities between and within Haiti and the Dominican Republic, the two constituent countries of the island of Hispaniola, using data from their respective Demographic and Health Surveys. Transnational socioeconomic rankings reveal a large and increasing divergence in wealth between the two countries, which would be ignored using the county-by-country approach. We find that wealth-related inequalities in long-term children’s health outcomes are larger than inequalities in short-term health outcomes, and decompositions of the influence of place-based variables on these inequalities reveal country of residence to be the most important factor for long-term outcomes, while urban/rural residence and subnational regions are more important for short-term health outcomes. The significance of this novel methodological approach in relation to conventional health inequality research, including hidden dimensions of wealth-related health inequalities, for example the urbanized “middle class” distribution of HIV and a hidden unequal burden of wasting among children uncovered by the transnational approach are discussed, and errors in gauging changes in inequality over time using a country-by-country approach are highlighted. Using the transnational approach can help to measure important trends in wealth-related health inequalities across countries that more commonly used methods traditionally overlook.

1. Introduction

Health inequality research has matured into a well-recognized field with dedicated journals, funding sources, and institutional support within governmental and non-governmental agencies. With the advent of the Sustainable Development Goals (SDG), reducing inequalities within and between countries as detailed in Goal 10 is now an explicitly recognized global objective demanding internationally standardized measurement techniques (\textit{United Nations, 2015}). While some effort has been made towards developing indices to measure global convergence in health outcomes across countries (Sachs, Schmidt-Traub, Kroll, Durand-Delacre, & Teksoz, 2016), empirical research quantifying and comparing socioeconomic inequality in achieving SDG health targets at a multi-country level has been limited. There have been calls for additional research to investigate health inequalities at this level (GBD 2015 SDG Collaborators, 2016; Hosseinpoor & Bergen, 2016; McKinnon, Harper, Kaufman, & Bergvin, 2014), but the methodological foundation for international comparisons in health inequalities has yet to be formally developed. Given the limited attention that has been given to this topic in the global health inequality measurement field, there is a need for the development of new measures to compare health inequalities across countries and over time.

Most studies of wealth-related health inequalities are typically limited to a single country or subregion (i.e. province, state, district, etc.) and use summary measures such as the concentration index, relative index of inequality, slope index of inequality, generalized entropy index, or similar measure to quantify inequality (Kakwani, Wagstaff, \& van Doorslaer, 1997; Marmot et al., 1991). The most common ranking measures of socioeconomic status (SES) that health inequality researchers have used include...
years of education (Fortson, 2008), income (Mújica, Vázquez, Duarte, & Cortez-Escalante, 2014), and household expenditure (Mokdad et al., 2015), however, in global health the most commonly used measure across countries is the household asset index (Davidson R, Gwatkin et al., 2007; McKinnon et al., 2014; Van De Poel, Hosseinpoor, Speybroeck, Van Ourti, & Vega, 2008; Wang, 2003). This technique is based on an accounting procedure that records the presence of typical household assets and calculates an index, often using the method of principal components analysis (PCA) adapted for household SES ranking by Filmer and Pritchett (2001), to calculate the relative well-being of households. The wealth index is now included as a standard feature in all Demographic and Health Surveys (DHS) as both a raw score and as quintiles of households ranked by raw score (Rutstein, 2008).

The validity and implicit value judgements of each measure of inequality have been well described for single-unit studies (Harper et al., 2010), but an increasing number of researchers are now using these measures of SES to construct measures of health inequality across more than one country or subregion and over time.

In response to the increasing interest being paid to comparisons of inequalities in global health, some studies have begun compiling, comparing, and even averaging health inequality summary measures across countries using a country-by-country approach (Li, Li, Subramanian, & Lu, 2017; McKinnon et al., 2014; Paraje, 2009; Van De Poel et al., 2008), or are polar opposites of very high and very low inequality in health (Cardona, Acosta, & Bertone, 2013; Gakidou & King, 2000; Wagstaff, 2002a), with some even presenting conflicting conclusions within the same study. It is possible that these conflicting findings can be attributed to the use of different methods of combining absolute and relative health inequality measures between two countries with very different levels of absolute wealth and health but similar patterns of disease distribution. This is because if the poorer country has a high burden of disease throughout the SES spectrum of its population, a summary measure of wealth-related health inequality may still be quite low, and conversely, a rich country with a very low burden of disease may not result in a large summary measure due to semi-random dispersion in its distribution. The effects of ignoring these differences can be further exacerbated by comparing countries over time. If there are larger increases in absolute wealth in one country or changes in the distribution of wealth in either country, making comparisons with the assumption of relative wealth parity would become invalid; even if the distribution of health outcomes within each unit does not change (Hosseinpoor et al., 2016; Wagstaff, Bredenkamp, & Buisman, 2014). The effects of ever-changing living standards between countries and the varying levels in health inequalities both within and between countries have therefore been continually analyzed as distinct and unrelated phenomena.

In addition to the variety of measurement errors that can arise from different combinations of wealth and health inequalities, the method by which wealth is measured can also have a distortionary effect. Since household asset indices calculated using the most common method of PCA have no meaningful scale (Filmer & Pritchett, 2001), the magnitude of wealth inequality may appear to be different even if absolute wealth levels are equal, or else may appear to be the same even when vast differences in wealth present. If researchers use a scale-dependent measure of inequality or attempt to compare two countries with separately calculated asset indices, this illusion can lead to the appearance of differences in health inequalities even when none are present. Stated differently, it may be clear that a household earning $50,000 is qualitatively different than a household earning $10,000, even if both households are in the highest-earning quintiles of their respective countries, but this difference can be less apparent to researchers if both households have an identical 5.5 household asset index value in the survey data. In sum, depending on the method used to quantify SES and absolute inequalities in health and wealth, comparing the magnitude of wealth-related health inequalities across countries using a country-by-country approach can produce misleading results— a methodological blindness which we propose to address using a new approach.

In this paper, we develop a new methodology to compare estimates of wealth-related health inequalities between countries and over time, an approach we call the transnational approach. To demonstrate its usefulness and the limitations of the country-by-country approach, we first demonstrate the distortionary effects of differences in health and disease prevalence within and between countries on overall differences in health inequalities across countries using simulated survey data. Second, we empirically construct measures of health inequalities across two countries, Haiti and the Dominican Republic, using both the country-by-country approach and the transnational approach. To do so, we begin with a discussion of specific methodological and practical issues that affected our ability to compare these two countries including selecting which countries to compare, identifying an appropriate data source that is comparable across countries or subregions, measuring SES on a common scale across countries, and deciding on an appropriate health inequality measure for transnational health inequality measurement. Our main finding is that the transnational approach identifies very different trends in cross-country health inequalities and that the transnational approach allows us to observe important differences in health inequalities that we could not observe using the country-by-country approach. We discuss the limitations of this approach and instances when we believe it would be more appropriate than more commonly used approaches to measure differences in health inequalities across countries.

2. Approaches to comparing health inequalities across countries

Rather than combining disparate measures of wealth and health using a bottom-up country-by-country approach, a top-down transnational approach allows us to address confounders which have affected this emerging field. At the most basic level, the transnational approach is simply the analysis of wealth-related health inequalities with every person or household in the area of study ranked using one unified SES measure rather than attempting to compare two or more countries with separate and in-comparable SES rankings. The utility of this type of analysis has previously been demonstrated in the decomposition of health inequalities into within- and between-provincial components in Canada (Jimenez-Rubio, Smith, & van Doorslaer, 2008). The institutional design of Canada’s federated health institutions means it can be treated as a proxy for the study of international health with provinces representing the same type of variation as might be seen in a country-by-country analysis, demonstrating that transnational health inequality analysis is theoretically possible. The primary obstacle to extending this style of analysis to the level of international health lies in the comparison of SES between countries, as one cannot simply use a common currency or an assumption of formal and relatively stable household incomes. However, it is possible to overcome this obstacle using common methods of household asset index creation to extend analysis from the within-country scale to the scale of multiple countries, bringing with it more significant health inequalities and greater policy diversity inherent in international research and leading to findings which are not apparent using any other method.
Although the lack of income or expenditure data in most household health survey of low- and middle-income countries may seem to be a significant challenge, the common practice of using a household asset index to rank SES can be used to generate a transnational ranking. The asset index measures a different dimension of SES than income or household expenditure that is more indicative of long-term SES than short- or medium-term income, and as such may not yield the same relative rankings (Howe, Hargreaves, Gabrysch, & Hutty, 2009). However, since they are derived from household assets, these indices can be easily measured, remain relatively stable over time, and can be directly compared across national boundaries – all major advantages over income or expenditure data which can fluctuate dramatically and can be difficult to measure accurately in developing contexts (Bollen, Glanville, & Stecklov, 2002; Sahn & Stifel, 2003). The main challenge in using this measure comes from the fact that although asset indices effectively rank each household relative to others in the sample, the numeric value of each index has no inherent value – it is an ordinal, but not an interval variable. Nevertheless, with care to ensure all household assets are directly comparable, one can pool two or more household surveys together, create a new transnational asset index using common methods such as PCA, and then analyze the within- and between-country components of health inequalities, as demonstrated by Jimenez-Rubio et al. (2008). While the fundamental approach is straightforward, the consequences of using the transnational approach in place of the currently accepted practice of country-by-country comparisons of international health inequalities are far from trivial.

To demonstrate the differences between the country-by-country and transnational approaches to estimating differences in health inequalities, we simulate the theoretical impact of changes in both income1 and disease inequality within and across countries using simulated survey data. A “poorer” country (mean income $30,000) and a “richer” country (mean income $40,000) with normally distributed and overlapping incomes were randomly assigned different prevalence levels of a disease according to transnational quintile, representing the entire SES distribution of both countries divided into five equal parts. Individuals were randomly assigned a hypothetical disease outcome varying randomly from a 0.65–0.75 level in countries divided into five equal parts. Individuals were randomly assigned different prevalence levels of a disease according to transnational quintile, representing the entire SES distribution of both countries divided into five equal parts. Individuals were randomly assigned a hypothetical disease outcome varying randomly from a 0.65–0.75 level in the poorest transnational SES quintile to 0.25–0.35 in the richest transnational quintile. This disease distribution is meant to represent disease outcomes which are more prevalent both in poorer countries and among lower SES status within countries. Parameters of both between- and within-country income inequalities and health inequalities were then varied to observe the relative effect of both transnational and country-specific income-related health inequalities.4

In Table 1, we present the differences that each of these effects have on the direction of both within- and between-country health inequalities, several of which would be undetectable or produce counterintuitive results using country-by-country methods. For example, error #1 identifies a situation in which reducing between-country health inequality by improving health outcomes in the poorer country increases health inequality within that country but decreases transnational inequality. Therefore, if a researcher were to use a country-by-country approach and simply count the number of countries that had experienced increases in health inequalities or take an average of country-level health inequalities – a method which has been used in published literature – one would conclude that overall inequality in the two countries had increased rather than decreased. An increase or decrease of between-country income inequality with disease prevalence staying the same, as described in errors #2 and #3, would result in changes to transnational inequality, but country-by-country inequality remaining exactly the same. Similarly, increasing within-country income inequality in either the poorer or richer country, as described in errors #4 and #5, would decrease transnational inequality, but be completely

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1 Although most transnational wealth-related inequality issues are related to the use of household asset indices, income is used as the ranking measure in the simulation for ease of understanding.
2 Appendix Table 1 presents concentration indices for each scenario.
undetected using country-by-country methods. Given the many threats to validity demonstrated in the simulated survey data, there is clearly justification for the use of transnational health inequality research, but the feasibility of doing so using real-world data must first be considered.

3. Empirical example: Wealth-related health inequalities in Hispaniola

To best demonstrate the utility of the transnational approach, case selection for our empirical demonstration was guided by three factors – a clearly demarcated jurisdictional or physical boundary for each individual jurisdiction and for the transnational unit, a most-different (i.e. extreme case) case selection approach, and data availability. These criteria were chosen to explore cases which most closely match the simulated composition effects identified in Table 1 while reducing the influence of confounding effects such as differing cultural contexts, conflict zones, or environmental/ecological differences. The contrast afforded by an “extreme case” and “most different case” selection logic has the advantage of highlighting transnational inequalities that may be overlooked using country-by-country methods of analysis (Seawright & Gerring, 2008). These considerations led to the selection of Haiti and the Dominican Republic, which together constitute the island of Hispaniola.

The physical boundary formed by the limits of the shared island provide an ideal and intuitive delimitation for the frame of analysis. The shared terrain has shaped the economic development and the public health challenges faced by both countries, but despite their shared geography, each country has undergone remarkably divergent paths of development. Whether the measure is gross national income (GNI) per capita, human development index, life expectancy, or infant mortality rate; Haiti has long endured the lowest quality of life measures in the Western Hemisphere, and has consistently fared worse than the neighboring Dominican Republic with an 11 year gap in life expectancy and a GNI per capita more than eight times lower than its richer neighbor in 2016 (The World Bank, 2017). The disparity between these countries has not gone unnoticed among health inequality researchers. More than fifteen years ago, Adam Wagstaff posed a prescient question - why is it “that the two countries that occupy the Caribbean island of Hispaniola-the Dominican Republic and Haiti-have such markedly different levels of inequality in child malnutrition and mortality?” (Wagstaff, 2002a, p. 10). He concluded that Hispaniola is an illustrative case of the tendency for health inequalities to increase as per capita incomes increase and as concomitant gains in health outcomes begin to take root among those benefiting from economic growth – the same effect identified in our transnational composition effect simulation.

Several studies have investigated health inequalities in Haiti (Arsenault et al., 2017; Danquah et al., 2015; Fenn, Kirkwood, Popatia, & Bradley, 2007; Gwatkin et al., 2007a) and in the Dominican Republic (Gwatkin et al., 2007b; Wagstaff, 2002b) separately. In addition, a number of studies have also contrasted measures of health inequalities across the two countries using country-by-county methods. One study found Haiti to have the largest inequalities in health of any country in the Latin American and Caribbean (LAC) region using an index of health and socioeconomic factors, while the Dominican Republic was ranked sixth worst out of 20 total countries in the same analysis (Cardona et al., 2013). In contrast, another cross-country comparison using DHS data noted that although Haiti had the lowest levels of inequality in child malnutrition in the LAC region, this obscured the fact that it had one of the highest absolute levels of child malnutrition in the region (Panjie, 2009). These seemingly contradictory findings can be explained by the limitations in making comparisons across countries using different reference points for both wealth and health; the best performing country in the first case, and own population in the second case. Thus, depending on the reference point, completely contradictory findings can be obtained due to fundamental tension that cannot be resolved using a country-by-country frame of analysis – more examples of the errors we identified in our simulation. Absolute differences in health inequalities across countries and inequalities within countries can be compared, but the magnitude of wealth-related inequalities among the population of Hispaniola as a whole cannot be measured using the current paradigm.

Having selected cases for analysis, the challenge of identifying an appropriate data source to pool over the two countries was solved using DHS data, which offer seven waves of more than 300 household surveys in over 90 countries with directly comparable health outcomes collected over three decades by international researchers in conjunction with country officials (Corri, Neuman, Finlay, & Subramanian, 2012). Health outcomes included in these datasets are mainly focused on maternal and child health, but certain countries have chosen to add country-specific modules. Directly measured outcomes always include children’s height and weight, and sometimes include laboratory test results for other outcomes such as anemia, human immunodeficiency virus (HIV), and malaria. These direct measures are complemented by self-reported health outcomes regarding child mortality, cough, diarrhea, and fever. An additional advantage of using DHS data is the availability of georeferenced data, which have been previously used to map children’s health outcomes across several African countries (Burke, Heft-Neal, & Bendavid, 2016; Kazembe & Mpketula, 2010). Using these techniques, subregional differences within countries can point to environmental or political determinants of health that would be overlooked using summary indicators, and more relevant to this study, sharp discontinuities across national boundaries can be suggestive of country-specific determinants of health (Burke et al., 2016).

The Dominican Republic has participated in every wave of DHS since its inception in 1986 (DHS-I to DHS-VI), while Haiti has participated since 1994 (DHS-III to DHS-VI). The analysis was restricted to women of reproductive age and their children, because adult men are only sampled as a subsample of the women’s household surveys and the sample is therefore relatively underpowered and non-representative (IcF International, 2012). To capture a variety of distributions of inequalities in health, every health outcome (excluding healthcare utilization variables) present in surveys for both countries were analyzed (Appendix Table 2). Children’s nutritional health outcomes are widely recognized to be crucial to public health and are generally more sensitive to living standards than adult health outcomes (Marmot, 2005). Therefore, the directly measured outcomes of underweight, stunting, and wasting were all converted to binary outcomes (z-scores two standard deviations below zero), because of the limited and uncertain influence of positive z-scores on children’s health in this context.7 Self-reported outcomes of children’s fever, cough, and diarrhea in the last two weeks were also included as indicators of short-term children’s health. From the women’s dataset, a ratio of self-reported children’s deaths to live births was included as a proxy for infant mortality, and blood tests for HIV status were included to observe whether infectious diseases exhibited a different pattern of inequality.8 All calculations were performed using STATA version 13 (StataCorp LP, College Station, Texas).
TX) and survey weights were included in all relevant calculations with poststratification adjustment according to each country’s population. In addition to these summary measures, georeferenced data was available for both Haiti and the Dominican Republic in waves five and six. Using these georeferenced data, the geography of health inequality throughout Hispaniola was investigated using ArcGIS (ESRI, Redlands, CA). The prevalence of disease for each survey cluster was mapped using global positioning system coordinates, and both spline interpolation and kriging methods were used to produce smoothed disease outcome maps (Auchincloss, Gebreab, Mair, & Diez Roux, 2012; Auchincloss, Diez Roux, Brown, Raghunathan, & Erdmann, 2007). Although waves three and four did not include georeferenced data, the earliest available shared survey (wave three) was analyzed for both countries to track the evolution of inequalities over time.

Despite the DHS offering a rich source of information for health outcomes in both countries, the surveys generally do not contain income or household expenditure data – a common challenge present in many household health surveys. This led us to create a new household asset index for the entire transnational sample for each of DHS waves three (1994–1996), five (years 2005–2007) and six (2012–2013). Household asset data was first closely examined and recoded to ensure direct comparability between both countries before a transnational asset index was calculated for each wave. With socioeconomic ranking of the transnational dataset complete, quantification of wealth-related health inequalities was conducted using the concentration index. We calculated the concentration index using methods described by O’Donnell, van Doorslaer, Wagstaff, and Lindelow (2008) and concentration indices for all binary variable outcomes were corrected using the Wagstaff (2005) method. Concentration indices are represented graphically as concentration curves, which represent all individuals ranked in order of lowest to highest SES along the x axis, with the cumulative share of disease plotted on the y axis, usually contrasted against a 45-degree diagonal line of equality for

Fig. 1. Transnational and country-by-country wealth index spline interpolation for waves five and six.

Fig. 2. Pen’s Parades of polychoric PCA wealth indices for waves three (left), five (center) and six (right).

9 Postweights based on population under 5 for children’s recode and women aged 15–49 for women’s recode variables using United Nations population data.

10 Only assets included in both country surveys were included for analysis, resulting in a range of 26 (wave three) to 52 (wave six) assets included for analysis. One wealth index was created with the same methodology used by the DHS Program (Filmer & Pritchett, 2001; Rutstein, 2008), including rescaling of rural and urban households with a secondary regression, and another wealth index was calculated using polychoric PCA. Given the more desirable statistical properties of polychoric PCA (Kolenikov & Angeles, 2009) and minimal difference between the two indices, polychoric PCA wealth index values are used as the default in this analysis.

11 An alternative method of addressing binary outcome variables is the Erreygers method (Erreygers, 2009; Erreygers & Ourti, 2012). Since we are more interested in relative inequality of health than absolute inequality and compare only outcomes of ill health rather than good health the Wagstaff correction is appropriate (Kjellsson & Gerdtham, 2013) and represents the more widely used method in global health literature.
reference. The concentration index has a value ranging between -1 and 1 which corresponds to two times the area between the line of equality and the concentration curve; or the percentage of the total outcome of interest that would have to be redistributed from the richest half to the poorest half of the population to reach a state of equality (Koolman & van Doorslaer, 2004; O’Donnell et al., 2008; Wagstaff, Paci, & van Doorslaer, 1991). We therefore exploit the fact that the concentration index is unaffected by a non-interval SES variable and proceed to decompose the index into its constituent parts.

The decomposition of the concentration index has been used to tease out factors which contribute to social inequalities in health as well as whether the factors contribute to larger or smaller inequalities. Studies using this approach do so for two main reasons. The first type attempts to identify possible causal factors which determine population social inequality in health, such as education, national income growth rates, or healthcare system characteristics (Goings & Firebaugh, 2004; McGrail, van Doorslaer, Ross, & Sammartin, 2009; Sahn & Younger, 2006). The second approach does not attempt to identify causal factors that explain patterns of inequality, but investigates the relative distribution of inequality among groups, often investigating the degree to which inequalities are distributed within geographical regions or between geographical regions (Pradhan, Sahn, & Younger, 2003). Within the Canadian context, for example, studies have decomposed health outcomes and healthcare use inequalities into both causal (Allin, 2008) and distributional (Jimenez-Rubio et al., 2008) types. With respect to our empirical demonstration, using the distributional decomposition approach means that besides removing the possibility of analytical errors demonstrated in the simulation, the transnational approach can identify the ways in which disadvantaged regions shift over time and the degree to which they are distributed between and within countries. Our concentration indices were therefore decomposed into three principal geographical constituents – the cross-country component, the within-country subregional component, and the urban-rural component. Having addressed the major challenges of justifying cases for inclusion, using high-quality comparable data, ranking households according to a common SES scale, quantifying the magnitude of inequalities in health on a transnational scale, and decomposing these inequalities according to their distributional components, we proceed to describe the results of the first empirical demonstration of transnational health inequality decomposition in Haiti and the Dominican Republic.

4. Results

A map of transnational household asset index values (Fig. 1, top) from highest (green) to lowest (red) clearly demonstrates a sharp disparity in wealth between the two countries. It is important to note that borders are presented for visual aid only and did not affect wealth index calculation or interpolation in any way. This makes the sharp divide which nearly identically coincides with the Haitian-Dominican border all the more striking. Going past this clear contrast, there are, nonetheless, areas of relative wealth and deprivation in both countries. The Dominican Republic’s pockets of relative deprivation are observed in mountainous and rural areas and are fewer in number in wave six. Haiti’s pockets of relative affluence are nearly all concentrated around major cities of Port-au-Prince, Cap-Haitien, Saint Marc, Gonaïves, and Les Cayes. In contrast, mapping country-specific values of the same index values (Fig. 1, bottom) displays no such contrast. While the areas of relative wealth within each country are the same, there is no discernible wealth disparity between countries, an effect which is guaranteed by the use of country-by-country methods, and which could produce counterintuitive results if interpreted naively. In effect, the country-by-country maps are a visual representation of how wealth data can be misleadingly used to erase real and meaningful differences in household SES.

Pen’s Parades presented in Fig. 2 order each country’s households from lowest to highest SES from left to right according to each wave’s transnational asset index values – a comparison which would be impossible using country-by-country analysis. Although the units of the index are not inherently meaningful, the relative standing of each household within each wave reveals that Dominican respondents are consistently wealthier than their Haitian counterparts. Even more revealing, Dominicans are increasingly wealthier as time goes on. In wave three, both the “poorest” and the “wealthiest” Haitian respondents were almost as wealthy as the equivalent Dominican respondents. In wave five, however, the poorest Dominican respondents were about at wealthy as the median Haitian respondents, and the wealth disparity only worsened in wave six, recreating several conditions identified as potential confounding in the simulated survey data.

Moving from wealth to health, maps of health outcomes (Fig. 3) represent higher prevalence of each outcome with red shading. The acute children’s health outcomes seen in the top three rows of Fig. 3 are fairly evenly dispersed throughout both countries, with the exception of cough, which appears to be slightly more prevalent in Haiti. In contrast, there are clearly more high-prevalence clusters for the three long-term outcomes of underweight, stunting, and wasting on the Haitian side of the border. Health outcomes from the women’s surveys, however, display two very different distributions of disease. Just as long-term children’s health outcomes, child deaths are clearly more prevalent on the Haitian side of the border, but high-prevalence clusters of HIV appear to be spread evenly throughout the island.

Delving deeper into these outcomes, Haitian survey respondents more frequently reported higher rates for every negative health outcome than respondents in the Dominican Republic. Concentration indices for each of these outcomes are presented in Table 2. Country-by-country concentration indices indicate a significant difference between Haiti and the Dominican Republic at the 95% level in only eight of 23 outcomes analyzed, with child deaths and HIV status most likely to be significantly different. In contrast, the transnational sample consistently results in higher concentration indices, which is caused both by the disparities in wealth between the two countries and by the higher prevalence of each outcome in Haiti – yet another hidden effect predicted in the simulation exercise. This effect can be more clearly

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12 Subregions were recoded in waves five and six to be directly comparable using ten Haitian departments and nine Dominican health regions, however wave three only contained three Haitian divisions (north, metropolitan, south).

13 Rather than only using within- and cross-country variables to decompose following Jimenez-Rubio (2008), urban-rural status was added to account for a possibly significant confounding factor. Subregions were used as fixed effect variables, while urban-rural and country were used as the primary decomposition variables.

14 Alternative specifications of PCA wealth index and kriging interpolation are presented in Appendix Figs. 1 and 2, but do not affect these results significantly.
seen by plotting the concentration curves. For example, Fig. 4 shows that for
the outcome of wasting in wave five, both Haiti and the Dominican Republic
have no significant wealth-related inequalities in the distribution of wasting
within their borders, however, due to the much higher prevalence in the
lower SES country, the transnational sample has a highly significant pro-rich
inequality of distribution for the island as a whole. Finally, changes in wealth-
related health inequalities over time for both the country-by-country ap-
proach and for the transnational approach result in diametrically opposite
conclusions in eight out of the fifteen measures that can be compared from
wave to wave, and there are large differences in magnitude for those that are
at least aligned in direction.

Panel 1. Concentration curves for children’s health outcomes in
wave three (top), wave five (middle), and wave six (bottom) for
transnational sample, Haiti, and Dominican Republic.

Panel 2. Concentration curves for child deaths and HIV status in
wave three (top), wave five (middle), and wave six (bottom) for
transnational sample, Haiti, and Dominican Republic.

Concentration curves for both countries and for Hispaniola are
presented for children’s health outcomes in Panel 1, and women’s
health outcomes in Panel 2. For the transnational analysis, every out-
come is disproportionately concentrated among the poor, with under-
weight, stunting, and wasting consistently being the most inequitably
distributed outcomes, while fever, cough, and diarrhea are relatively
more equitably distributed throughout the socioeconomic spectrum of
Hispaniola. For example, in wave five more than 60% of underweight

children were found within the poorest third of the population of
Hispaniola and over 80% of underweight children were within the
poorest half of the population. These wealth-related inequalities in
child health outcomes worsened between waves three and five, but
Distributional decompositions of each concentration index are presented in Appendix Tables 10–12. Wealth itself is not included in the decomposition because household asset index values have no meaningful scale.

Inequality analysis for each health outcome is driven by country of residence in every wave, with lesser contributions of subregions and urban-rural status. These previously hidden trends in the geographic distribution of adverse health outcomes in Hispaniola have significant implications for health inequality research.

5. Discussion

The empirical results of this first transnational wealth-related health inequality analysis demonstrate that the distribution of wealth and of health outcomes across countries affects the estimation of health inequalities in country-by-country comparisons and that these limitations can be overcome using the same sources of data currently used in the literature. The transnational wealth index analysis confirms a large and increasing divergence in household wealth between Haiti and the Dominican Republic over time. However, poorer Dominican respondents living primarily in rural areas are still not as wealthy as the far fewer relatively wealthy Haitian respondents living primarily in urban areas. Acute child health outcomes of fever, cough, and diarrhea are common throughout the island, and decomposition results do not identify a consistent geographic driver of inequality among these outcomes. In contrast, the long-term child health outcomes of underweight, stunting, and wasting were all much more prevalent in Haiti. It appears that this is not attributable to differential incidence of short-term disease, rather, the extremely high concentration index values point to long-term wealth-associated determinants such as nutrition, living conditions, and healthcare access. The ratio of child deaths follows the same mould as these long-term health outcomes, albeit at slightly lower levels of wealth-related inequality. In contrast to these long-term health outcomes, HIV status exhibits a very different distribution. The magnitude of wealth-related inequality is just as large as child deaths, but the decomposition identifies country of residence to be a major driver of inequality, with urban/rural status reducing this inequality significantly. This is because HIV status is the only health outcome which is more prevalent in urban areas, which are relatively wealthier than rural areas in both countries. Looking at the wealth-related inequalities in health over time, it is encouraging that following increases from waves three to five, a decrease in wealth-related inequality for every health outcome has started to take hold.

Researchers investigating global health inequalities should take note of several aspects of these empirical results. First, limiting analysis of health inequalities to country-by-country comparisons effectively ignores the influence of shifting levels of national disease prevalence.

23 This may be partially attributed to recall bias since these outcomes are not directly measured, but the relative rate at which parents recalled their children falling ill within the last two weeks of being surveyed was fairly consistent from wave to wave.

24 The impact of the devastating 2010 earthquake can certainly not be overlooked, and the health outcome one might have most expected to be affected would be child deaths. Nonetheless, the ratio of child deaths observed in the sample falls continuously from waves three to five for both countries, and the Port-au-Prince area does not appear to have a markedly higher child death ratio than surrounding areas in Haiti.

| Wave Five | Wave Six |
|-----------|----------|
| Fever     | Fever    |
| Cough     | Cough    |
| Diarrhea  | Diarrhea |
| Underweight | Underweight |
| Stunting  | Stunting |
| Wasting   | Wasting |
| Child Deaths | Child Deaths |
| HIV       | HIV      |

Fig. 3. Health outcome maps for DHS waves five (left) and six (right) for fever, cough, diarrhea, underweight, stunting, wasting, child deaths, and HIV status (top to bottom).
absolute wealth, and inequalities in both wealth and health. A researcher could conclude, for example, that wealth-related inequalities in wasting had gone from very low levels in wave three to non-existent in waves five and six using country-by-country comparisons. However, using a transnational sample, the large inequalities primarily driven by country of residence and subregion become clear. Complex distributions of disease can also be made clear, as demonstrated by HIV prevalence in waves five and six. Rather than simply finding that richer Haitians and poorer Dominicans are more likely to be HIV prevalent, a picture emerges of relatively “middle class” urban residents of Hispaniola having an elevated risk of infection. Even attempting to consider the relative distribution of wealth seen in Fig. 1 would be impossible if country-by-country methods were used.

Examining the change in health inequalities from wave to wave clearly reveals the hidden effects we hypothesized in our simulated data. Changes in wasting inequalities from wave five to wave six, for example, would lead a researcher believe that since wealth-related inequalities had increased in both countries, the overall inequality must

### Table 2
Concentration indices for Haiti, the Dominican Republic, and transnational sample with a country-by-country average and differences between both countries and survey waves.

| Wave Three | Haiti  | DR    | Haiti-DR Difference | p-value | Country-by-country | Transnational |
|------------|-------|-------|---------------------|---------|--------------------|---------------|
| Stunting   | -0.275 | -0.452| -0.177              | 0.00*   | -0.364             | -0.495        |
| Underweight| -0.254 | -0.492| -0.238              | 0.00*   | -0.373             | -0.537        |
| Wasting    | -0.125 | -0.176| -0.051              | 0.69    | -0.151             | -0.400        |
| Diarrhea   | -0.061 | -0.135| -0.073              | 0.06    | -0.098             | -0.208        |
| Fever      | -0.085 | -0.068| 0.016               | 0.68    | -0.077             | -0.158        |
| Cough      | -0.065 | -0.094| -0.03               | 0.42    | -0.080             | -0.159        |
| Child Deaths| -0.069| -0.189| -0.12               | 0.00*   | -0.129             | -0.259        |

| Wave Five  | Haiti  | DR    | Haiti-DR Difference | p-value | Country-by-country | Transnational | Country-by-country change | Transnational change |
|------------|-------|-------|---------------------|---------|--------------------|---------------|--------------------------|----------------------|
| Stunting   | -0.316 | -0.265| 0.051               | 0.31    | -0.291             | -0.579        | 0.073                    | -0.084               |
| Underweight| -0.23  | -0.314| -0.084              | 0.13    | -0.272             | -0.694        | 0.101                    | -0.157               |
| Wasting    | 0.007  | 0.01  | 0.003               | 0.97    | 0.09               | -0.503        | 0.159                    | -0.103               |
| Diarrhea   | -0.06  | -0.061| -0.001              | 0.98    | -0.061             | -0.186        | 0.038                    | 0.022                |
| Fever      | -0.041 | -0.02 | 0.021               | 0.6     | -0.031             | -0.120        | 0.046                    | 0.038                |
| Cough      | -0.045 | -0.056| -0.011              | 0.79    | -0.051             | -0.233        | 0.029                    | -0.074               |
| HIV        | 0.044  | -0.266| 0.31                | 0.00*   | -0.111             | -0.339        |                          |                      |
| Child Deaths| -0.116| -0.135| -0.019              | 0.36    | -0.126             | -0.278        | 0.004                    | -0.019               |

| Wave Six   | Haiti  | DR    | Haiti-DR Difference | p-value | Country-by-country | Transnational | Country-by-country change | Transnational change |
|------------|-------|-------|---------------------|---------|--------------------|---------------|--------------------------|----------------------|
| Stunting   | -0.246 | -0.265| -0.019              | 0.78    | -0.256             | -0.413        | 0.035                    | 0.166                |
| Underweight| -0.215 | -0.273| -0.058              | 0.42    | -0.244             | -0.388        | 0.028                    | 0.306                |
| Wasting    | -0.111 | -0.034| 0.077               | 0.42    | -0.073             | -0.290        | -0.081                   | 0.213                |
| Diarrhea   | -0.015 | -0.106| -0.091              | 0.04*   | -0.061             | -0.068        | 0.000                    | 0.118                |
| Fever      | -0.017 | -0.053| -0.036              | 0.34    | -0.035             | -0.073        | -0.005                   | 0.047                |
| Cough      | 0.036  | -0.066| -0.102              | 0.01*   | -0.015             | -0.219        | 0.036                    | 0.014                |
| HIV        | 0.082  | -0.322| -0.404              | 0.00*   | -0.120             | -0.245        | -0.009                   | 0.044                |
| Child Deaths| 0.071 | -0.133| -0.061              | 0.03*   | -0.102             | -0.234        | 0.024                    | 0.094                |

Fig. 4. Wave five wasting concentration curves for Haiti, Dominican Republic, and transnational samples.
Measuring inequality is not a mere quantitative exercise – it is an actualization of normative judgements. Decisions on whether to use relative versus absolute differences in wealth and which population to have increased using country-by-country methods. In spite of this, there was actually a substantial decrease in transnational inequality primarily due to error #1 identified in the simulated survey data. Just as significantly, changes in stunting, underweight, and wasting from wave three to five would have led a country-by-country researcher to a somewhat mixed conclusion. Wealth-related inequalities had decreased significantly in the Dominican Republic for each outcome, while there was either a decrease, an increase, or no change in inequalities in Haiti. This would have led a researcher to the uncertain but tempting country-by-country conclusion that inequality had probably been reduced overall. Despite this appearance, the transnational approach reveals that overall inequality had actually increased due to a combination of factors, including larger between-country income inequality and larger reductions in absolute prevalence in the richer country. When considering the overall picture of changes in the distribution of health and wealth over time in Hispaniola, these findings are unsurprising, however had a country-by-country approach been undertaken, they would have been completely overlooked.

The limitations of these findings mostly relate to survey data methods and difficulties in comparing data across national boundaries. Some health outcomes may be affected by recall or other biases inherent in survey methodology, but half of the outcomes presented are physically measured or lab tested, allowing for apples-to-apples comparisons between countries. It is possible that household assets are valued differently or are of different quality between Haiti and the Dominican Republic, meaning that direct comparisons of these assets would not be appropriate. Wealth indices, whether they are calculated using PCA or not, are not equivalent to household expenditure or income (Howe et al., 2009). This does not mean that the indices are any less valid, but rather that a separate dimension of SES is being measured. In fact, the greater stability over time, potential causal pathways from assets to health outcomes, and direct comparability between countries give wealth indices several advantages over measures based on national currencies or purchasing power parity equivalents. However, they have even led to promising research assigning an estimated national income distribution according to each household's relative asset index ranking, developed at least in part to address transnational SES measurement issues (Harttgen & Vollmer, 2013; Joseph, da Silva, Fink, Barros, & Victora, 2018). The effect of divergent country-level wealth and disease prevalence is large due to the extreme case selection method used in this study, however, there are many other countries which would likely produce similar results. The results should not be taken to be generalizable to any other contexts due to the case selection method, therefore, and further study should be conducted to reveal whether these trends are echoed in other regions of the world. Although the methods described are theoretically applicable in any country, household asset data are not routinely collected in more wealthy regions such as Europe, meaning that our findings are most applicable to low- and middle-income countries.

The transnational approach is informed by the rapidly growing field of global income and wealth inequality measurement, which primarily utilizes internationally standardized household surveys as data sources and inequality measures such as the Gini index and generalized entropy measures – tools and data sources which have direct analogues in the field of health. Although it has been a topic of theoretical discussion for well over a century, the first published empirical estimation of global income distribution (Milanovic, 2002) was only possible after the widespread implementation of household surveys in the developing world. Global income distribution estimates have since become more comprehensive, both in terms of population and years covered, and have been reinforced through the use of different methodologies and data sources (Darvas, 2016; Lakner & Milanovic, 2013). This research has begun to provide evidence that the within- and between-country composition of inequality changes over time and is sensitive to policy change and technological change. Additionally, research into the political geography of wealth inequality has begun to produce insights into the complex political and economic determinants of inequalities at different scales of analysis (Berali, 2012).

Building upon these theoretical foundations, the results of this empirical demonstration of transnational wealth-related health inequality analysis demonstrate the utility and validity of the approach in hopes of inspiring further research at this new scale. Transnational health inequality composition effects such as the divergent child death ratio and HIV status decompositions may point to new hypotheses regarding the determinants of these outcomes at a level not restricted by national boundaries, and clearly have implications for policies meant to address these disparities. Policymakers deciding how to allocate scarce resources at both national and international levels should be informed by empirical research to know which administrative levels to target with health interventions in order to have the greatest impact. In addition, decomposition of the geographic distribution of health outcomes is only one possible use of this approach. Analysis of specific infectious diseases which are endemic to a transnational region could benefit from pooling of data, and groupings of subregions according to primary economic activity or ecologic characteristics offer yet another avenue of research. The many possible applications of transnational health inequality analysis should be of interest to global health researchers, multilateral agencies, and all parties involved in measuring progress in achieving the SDG.

Measuring inequality is not a mere quantitative exercise – it is an actualization of normative judgements. Decisions on whether to use relative versus absolute differences in wealth and which population to
use as a reference point all imply normative judgements – whether they are acknowledged or not (Harper et al., 2010). By ignoring the transnational dimensions of wealth-related health inequalities using a country-by-country approach, the normative position has been to essentially to ignore these differences, or at least outside of the scope of policy. This effect is the result of a well-known process within political science by which the act of measuring itself creates political communities and heavily influences which issues reach the governmental agenda of policymakers (Kingdon, 2003; Stone, 2012). If transnational inequalities in health outcomes targeted by the SDG are politically determined – a hypothesis for which there is much supporting evidence (Ottersen et al., 2014) – then a first step towards a recognition of this pathway is rigorous analysis of the best available data to ensure that we are overlooking hidden dimensions of global health inequalities through inadequate methodology.

Appendix

See Appendix Tables 1–12 and Figs. 1, 2.

Appendix Table 1
Concentration indices for simulated survey data.

| Variable modified | Direction of modification | Poorer country concentration index | Richer country concentration index | Country-by-country conclusion | Transnational concentration index |
|-------------------|---------------------------|-----------------------------------|-----------------------------------|-------------------------------|----------------------------------|
| None (reference concentration index) | | -0.087 | -0.132 | -0.109 | -0.160 |
| Health inequality between countries | Convergence (poor reduces disease prevalence more than rich country) | -0.095 | -0.132 | -0.113 | -0.147 |
| | Divergence (rich reduces disease prevalence more than poor country) | -0.087 | -0.151 | -0.119 | -0.191 |
| Income inequality between countries | Convergence (poor catches up to rich) | -0.087 | -0.132 | -0.109 | -0.150 |
| | Divergence (rich becomes even wealthier than poor) | -0.087 | -0.132 | -0.109 | -0.157 |
| Health inequality within countries | Decrease in richer country | -0.087 | -0.045 | -0.066 | -0.106 |
| | Increase in richer country | -0.087 | -0.356 | -0.222 | -0.268 |
| | Decrease in poorer country | -0.039 | -0.132 | -0.085 | -0.119 |
| | Increase in poorer country | -0.149 | -0.132 | -0.140 | -0.218 |
| Income inequality within countries | Decrease in richer country | -0.087 | -0.121 | -0.104 | -0.156 |
| | Increase in richer country | -0.087 | -0.132 | -0.109 | -0.157 |
| | Decrease in poorer country | -0.080 | -0.132 | -0.106 | -0.156 |
| | Increase in poorer country | -0.087 | -0.132 | -0.109 | -0.157 |

Appendix Table 2
Description of DHS variables used for child health outcomes.

| Dataset Used | Variables | Variable Descriptions | Notes |
|--------------|-----------|-----------------------|-------|
| Children’s Recode | h22 | Has child had a fever in the last two weeks? | |
| Children’s Recode | h31 | Has child had a cough in the last two weeks? | |
| Children’s Recode | h11 | Has child had diarrhea in the last two weeks? | |
| Children’s Recode | hw8 | Weight-for-age Z-score (WAZ) | WAZ < -2 SD = Underweight |
| Children’s Recode | hw5 | Height-for-age Z-score (HAZ) | HAZ < -2 SD = Stunting |
| Children’s Recode | hw11 | Weight-for-height Z-score (WHZ) | WHZ < -2 SD = Wasting |
| HIV Dataset | hiv03 | Blood test result | Available for waves 5 and 6 only |
| Individual’s Recode | v201, v206, v207 | Total children ever born, sons who have died, daughters who have died | (v206 + v207)/v201 = Ratio of child deaths to live births |

* SD = Standard Deviations.

Ethics approval

Ethics approval is not required for this paper. We used only secondary, publicly available and deidentified DHS data in analysis and no primary human subject data was collected.

Declarations of interest

None.

Role of the funding source

There is no funding source associated with this research.
### Appendix Table 3
Spearman’s rho for all wealth indices.

| Wave   | Polychoric PCA | PCA | DHS Haiti Score | DHS DR Score |
|--------|----------------|-----|----------------|--------------|
|        | rho            | obs |                 |              |
|        |                |     |                 |              |
| Polychoric PCA | 1            | 24252 |                |              |
| PCA     | 0.9728        | 23587 | 1              | 23621        |
| DHS Haiti Score | 0.8771      | 13157 | 0.9001         | 13178        |
|         | 0.9022        | 11095 | 0.9203         | 10443        |
| DHS DR Score |              |       | 1              | 11464        |

| Wave   | Polychoric PCA | PCA | DHS Haiti Score | DHS DR Score |
|--------|----------------|-----|----------------|--------------|
|        | rho            | obs |                 |              |
|        |                |     |                 |              |
| Polychoric PCA | 1            | 39849 |                |              |
| PCA     | 0.9745        | 39849 | 1              | 39988        |
| DHS Haiti Score | 0.8965      | 9915  | 0.8069         | 9953         |
|         | 0.9462        | 29934 | 0.9003         | 30035        |
| DHS DR Score |              |       | 1              | 32431        |

### Appendix Table 4
Wave Three Children’s Summary Statistics.

| Dominican Republic | Age (months) | Stunting | Wasting | Underweight | Diarrhea | Cough | Fever | PCA | Polychoric PCA |
|--------------------|--------------|----------|---------|-------------|----------|-------|-------|-----|----------------|
| mean               | 29.4         | 0.131    | 0.016   | 0.078       | 0.170    | 0.417 | 0.298 | 0.385 | 0.105          |
| se(mean)           | 0.26         | 0.006    | 0.002   | 0.004       | 0.006    | 0.008 | 0.007 | 0.029 | 0.020          |
| N                  | 4413         | 3739     | 3740    | 3739        | 4288     | 4288  | 4285  | 4219 | 4219           |
| min                | 0            | 0        | 0       | 0           | 0        | 0     | 0     | 0    | -3.976         |
| max                | 59           | 1        | 1       | 1           | 1        | 1     | 1     | 4.764 | 2.320          |
| Haiti              | Age (months) | Stunting | Wasting | Underweight | Diarrhea | Cough | Fever | PCA | Polychoric PCA |
| mean               | 29.3         | 0.316    | 0.078   | 0.078       | 0.170    | 0.417 | 0.298 | 0.385 | 0.105          |
| se(mean)           | 0.31         | 0.009    | 0.005   | 0.009       | 0.008    | 0.009 | 0.009 | 0.026 | 0.016          |
| N                  | 3208         | 2740     | 2753    | 2740        | 3113     | 3099  | 3099  | 3542 | 3542           |
| min                | 0            | 0        | 0       | 0           | 0        | 0     | 0     | -4.259 | -3.150         |
| max                | 59           | 1        | 1       | 1           | 1        | 1     | 1     | 4.336 | 2.777          |
| Total              | Age (months) | Stunting | Wasting | Underweight | Diarrhea | Cough | Fever | PCA | Polychoric PCA |
| mean               | 29.4         | 0.209    | 0.042   | 0.161       | 0.217    | 0.463 | 0.346 | -0.563 | -0.530         |
| se(mean)           | 0.20         | 0.002    | 0.005   | 0.005       | 0.005    | 0.006 | 0.006 | 0.023 | 0.015          |
| N                  | 7621         | 6479     | 6493    | 6479        | 7401     | 7387  | 7384  | 7761 | 7761           |
| min                | 0            | 0        | 0       | 0           | 0        | 0     | 0     | -4.259 | -3.452         |
| max                | 59           | 1        | 1       | 1           | 1        | 1     | 1     | 4.764 | 2.320          |
### Appendix Table 5
Wave Three Individual's Summary Statistics.

| Dominican Republic | Age (months) | Stunting | Wasting | Underweight | Diarrhea | Cough | Fever | PCA | Polychoric PCA |
|--------------------|--------------|----------|---------|-------------|----------|-------|-------|-----|----------------|
| mean               | 28.8         | 0.064    | 0.047   | 0.167       | 0.287    | 0.224 | -0.751| 1.039| 0.584          |
| se(mean)           | 0.17         | 0.002    | 0.007   | 0.004       | 0.004    | 0.018 | 0.005 | 0.584| 0.666          |
| N                  | 8422         | 5942     | 9255    | 10587       | 10570    | 10276 | 10236 | 0.509| 0.666          |
| min                | 15           | 0        | 0       | 0           | 0        | 0     | 0     | 0.584| 0.666          |
| max                | 49           | 1        | 1       | 1           | 1        | 1     | 1     | 0.584| 0.666          |

### Appendix Table 6
Wave Five Children's Summary Statistics.

| Dominican Republic | Age (months) | Stunting | Wasting | Underweight | Diarrhea | Cough | Fever | PCA | Polychoric PCA |
|--------------------|--------------|----------|---------|-------------|----------|-------|-------|-----|----------------|
| mean               | 27.7         | 0.245    | 0.083   | 0.216       | 0.222    | 0.462 | 0.262 | 0.245| -3.405         |
| se(mean)           | 0.13         | 0.009    | 0.005   | 0.006       | 0.007    | 0.029 | 0.018 | 0.245| -3.405         |
| N                  | 10038        | 9255     | 9255    | 10587       | 10570    | 10276 | 10236 | 0.509| 0.666          |
| min                | 0            | 0        | 0       | 0           | 0        | 0     | 0     | 0.584| 0.666          |
| max                | 59           | 1        | 1       | 1           | 1        | 1     | 1     | 0.584| 0.666          |

### Appendix Table 7
Wave Five Individual's Summary Statistics.

| Dominican Republic | Age | Death Ratio | HIV Positive | PCA | Polychoric PCA |
|--------------------|-----|-------------|--------------|-----|----------------|
| mean               | 29.7| 0.041       | 0.008        | 1.237| 0.666          |
| se(mean)           | 0.06| 0.000       | 0.001        | 0.011| 0.666          |
| N                  | 27195| 19541       | 25452        | 25771| 25676          |
| min                | 15        | 0           | 0            | -7.158| 4.782          |
| max                | 49        | 1           | 1            | 3.907 | 3.256          |

| Dominican Republic | Age | Death Ratio | HIV Positive | PCA | Polychoric PCA |
|--------------------|-----|-------------|--------------|-----|----------------|
| mean               | 28.2| 0.101       | 0.025        | -2.708| -2.075         |
| se(mean)           | 0.10| 0.002       | 0.002        | 0.024 | 0.016          |
| N                  | 10757| 6547        | 5224         | 10709| 10651          |
| min                | 15        | 0           | 0            | -7.158| 4.782          |
| max                | 49        | 1           | 1            | 3.907 | 3.256          |
### Appendix Table 8
Wave Six Children's Summary Statistics.

| Country          | Age (months) | Stunting | Wasting | Underweight | Diarrhea | Cough | Fever | PCA | Polychoric PCA |
|------------------|--------------|----------|---------|-------------|----------|-------|-------|-----|----------------|
| Dominican Republic | 29.2         | 0.053    | 0.019   | 0.051       | 0.179    | 0.280 | 0.233 | 2.131 | 1.196          |
| se(mean)         | 0.3          | 0.004    | 0.002   | 0.004       | 0.006    | 0.008 | 0.007 | 0.027 | 0.018          |
| N                | 3387         | 3090     | 3188    | 3188        | 3560     | 3568  | 3570  | 3337 | 3358           |
| max              | 59           | 1        | 1       | 1           | 1        | 1     | 1     | 1    | 4.966          |
| Haiti            | 27.4         | 0.179    | 0.045   | 0.150       | 0.214    | 0.526 | 0.284 | -2.181 | -1.639         |
| se(mean)         | 0.3          | 0.006    | 0.003   | 0.006       | 0.005    | 0.006 | 0.006 | 0.022 | 0.014          |
| N                | 4074         | 3967     | 3968    | 3968        | 6598     | 6596  | 6617  | 7247 | 7240           |
| min              | 0            | 0        | 0       | 0           | 0        | 0     | 0     | 0    | -5.822         |
| max              | 59           | 1        | 1       | 1           | 1        | 1     | 1     | 1    | 4.824          |
| Transnational    | 28.2         | 0.124    | 0.034   | 0.106       | 0.202    | 0.440 | 0.266 | -0.822 | -0.701         |
| se(mean)         | 0.2          | 0.004    | 0.002   | 0.004       | 0.004    | 0.005 | 0.004 | 0.026 | 0.017          |
| N                | 7461         | 7057     | 7156    | 7156        | 10158    | 10164 | 10187 | 10584| 10820         |
| min              | 0            | 0        | 0       | 0           | 0        | 0     | 0     | 0    | -5.822         |
| max              | 59           | 1        | 1       | 1           | 1        | 1     | 1     | 1    | 4.966          |

### Appendix Table 9
Wave Six Individual's Summary Statistics.

| Country          | Age (months) | Death Ratio | HIV | PCA | Polychoric PCA |
|------------------|--------------|-------------|-----|-----|----------------|
| Dominican Republic | 29.8         | 0.039       | 0.009 | 2.458 | 1.435          |
| se(mean)         | 0.10         | 0.002       | 0.001 | 0.015 | 0.011          |
| N                | 9372         | 6687        | 8897 | 8804 | 9180           |
| min              | 15           | 0           | 0    | -4.258 | -3.348         |
| max              | 49           | 1           | 1    | 5.039 | 3.961          |
| Haiti            | 28.1         | 0.089       | 0.027 | -1.602 | -1.276         |
| se(mean)         | 0.08         | 0.002       | 0.002 | 0.017 | 0.011          |
| N                | 14287        | 8671        | 9326 | 14286 | 14249         |
| min              | 15           | 0           | 0    | -5.860 | -4.221         |
| max              | 49           | 1           | 1    | 5.495 | 3.465          |
| Total            | 28.8         | 0.067       | 0.018 | -0.054 | -0.214         |
| se(mean)         | 0.06         | 0.001       | 0.001 | 0.018 | 0.012          |
| N                | 23659        | 15358       | 18223 | 23090 | 23429         |
| min              | 15           | 0           | 0    | -5.860 | -4.221         |
| max              | 49           | 1           | 1    | 5.495 | 3.465          |

### Appendix Table 10
Decomposition of concentration indices for wave six.

| Country elasticity | Stunting | Underweight | Wasting | Underweight | Diarrhea | Cough | Fever | PCA | Polychoric PCA |
|--------------------|----------|-------------|---------|-------------|----------|-------|-------|-----|----------------|
| Country concentration index | -0.805    | -0.483      | -0.215   | -0.021      | -0.241   | -0.166 | -0.358 | 1.301 |
| Country contribution | -0.357    | -0.212      | -0.088   | -0.014      | -0.199   | -0.101 | -0.158 | -0.478 |
| Country percentage contribution | 0.911     | 0.514       | 0.289    | 0.179       | 0.857    | 1.332  | 0.581  | 1.394 |
| Urban/Rural elasticity | 0.388     | 0.325       | 0.352    | -0.115      | -0.096   | -0.077 | 0.134  | -0.247 |
| Urban/Rural concentration index | -0.123    | -0.122      | -0.114   | -0.150      | -0.190   | -0.141 | -0.110 | -0.099 |
| Urban/Rural contribution | -0.048    | -0.043      | -0.040   | 0.017       | 0.018    | 0.011  | 0.015  | 0.024 |
| Contribution of regional fixed effects | 0.077     | 0.055       | -0.152   | -0.066      | -0.036   | -0.052 | -0.035 | 0.165 |
| percentage contribution of regional fixed effects | -0.178    | 0.133       | 0.495    | 0.844       | 0.153    | -0.693 | 0.128  | -0.481 |
| residual | -0.107    | -0.103      | -0.026   | -0.016      | -0.016   | -0.038 | -0.065 | -0.054 |

* Bolded numbers are the primary outcomes, representing each variable's contribution to the concentration index. Elasticity, variable-specific concentration index, and percentage contribution are presented for as supporting information.

### Appendix Table 11
Decomposition of concentration indices for wave five.

| Country elasticity | Stunting | Underweight | Wasting | Fever | Cough | Diarrhea | Death Ratio | HIV |
|--------------------|----------|-------------|---------|-------|-------|----------|-------------|-----|
| Country concentration index | -0.600    | -0.766      | -0.663  | 0.070 | 0.015 | 0.069    | -0.343      | -1.508 |
| Country contribution | -0.227    | -0.283      | -0.229  | 0.043 | 0.012 | 0.040    | -0.145      | -0.421 |
Appendix Table 11 (continued)

| Country percentage contribution | Stunting | Underweight | Wasting | Fever | Cough | Diarrhea | Death Ratio | HIV |
|---------------------------------|----------|-------------|---------|-------|-------|----------|-------------|-----|
| Urban/Rural elasticity          | -0.052   | -0.107      | -0.099  | -0.152| -0.197 | -0.203   | -0.118      | -0.118|
| Urban/Rural concentration index | 0.474    | 0.272       | 0.862   | 0.619 | 0.326 | 0.864    | 0.409       | -0.087|
| Urban/Rural contribution        | -0.125   | -0.118      | -0.102  | -0.069| -0.069 | 0.027    | 0.266       | -0.130|
| Urban/Rural percentage contribution | -0.059  | -0.032      | 0.003   | 0.011 | 0.013 | -0.004   | -0.031      | -0.118|
| Contribution of regional fixed effects | -0.192 | -0.201      | 0.041   | -0.030| -0.078 | 0.047    | -0.070      | 0.260|
| residual                        | -0.164   | -0.154      | -0.094  | -0.040| -0.039 | -0.070   | -0.058      | -0.058|

* Bolded numbers are the primary outcomes, representing each variable’s contribution to the concentration index. Elasticity, variable-specific concentration index, and percentage contribution are presented for as supporting information.

Appendix Table 12

Decomposition of concentration indices for wave three

| Country percentage contribution | Stunting | Underweight | Wasting | Fever | Cough | Diarrhea | Death Ratio |
|---------------------------------|----------|-------------|---------|-------|-------|----------|-------------|
| Urban/Rural elasticity          | -0.125   | -0.118      | -0.102  | -0.069| -0.069 | 0.027    | 0.266       |
| Urban/Rural concentration index | 0.474    | 0.272       | 0.862   | 0.619 | 0.326 | 0.864    | 0.409       |
| Urban/Rural contribution        | -0.059   | -0.032      | 0.003   | 0.011 | 0.013 | -0.004   | -0.031      |
| Urban/Rural percentage contribution | -0.192  | -0.201      | 0.041   | -0.030| -0.078 | 0.047    | -0.070      |
| Contribution of regional fixed effects | -0.164 | -0.154      | -0.094  | -0.040| -0.039 | -0.070   | -0.058      |

* Bolded numbers are the primary outcomes, representing each variable’s contribution to the concentration index. Elasticity, variable-specific concentration index, and percentage contribution are presented for as supporting information.
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