Wealth Inequality and Health Achievement:
Relating novel measures of wealth distribution to child and maternal mortality

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Abstract

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Background GDP per capita is arguably the single most predictive determinant of health at the national level, yet such a measure fails to capture the complexity of wealth (and thus health) distribution within a population. Health at the individual level has been shown to be associated with asset-based measures of wealth, but the relationship hasn't been demonstrated consistently at the national level. Currently existing wealth and inequality measures are not comparable across surveys, across countries, or across time. In this thesis, I quantify wealth inequality using an asset-based measure by country and year, from 1990 to 2010, and study associations between inequality and several measures of health through the lens of the Millennium Development Goals.

Methods I generate a global asset-based wealth index that is comparable across countries and over time using 461 surveys from 140 countries, anchoring this scale on assets with low differential item functioning. I then translate this to an international dollar scale for the calculation of a modified Gini coefficient and ratio of 90^{th} to 10^{th} percentiles. I then investigate the relationship between such measures and child and maternal mortality in terms of levels, trends and thresholds of improvement in the Millennium Development Goal 4 & 5 targets after controlling for other known determinants of these health outcomes.

Findings Wealth-based inequality is consistently significantly associated with maternal and child mortality at the country level, regardless of inequality metric selected. A counterfactual scenario reducing inequality in 1990 by one standard deviation suggests that countries would have lower mortality rates now, would have seen more rapid progress in reducing mortality from 1990 to 2010, and that more would be on track to achieve the Millennium Development Goal targets.

Interpretation The observed associations between income inequality and health outcomes add new evidence to the debate around the possible detrimental effects of economic inequality. The findings here suggest that the reduction of economic inequality, through provision of services or redistributive policies, may be critical for improve health outcomes in the long run.

Table of Contents

Acknowledgements

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Background

Remarkable global progress has been made in improving health in the last twenty years. Deaths due to communicable disease, maternal conditions, and neonatal causes, for example, have fallen by nearly a third (29.9%) worldwide from 1990 to 2010.[1] Significant progress has been made towards achieving health-related Millennium Development Goals, namely reducing child mortality, maternal mortality, and addressing HIV, malaria, and TB.[2] This progress owes to a myriad of factors, including economic growth, increases in education, health systems improvement, and targeted delivery of effective and low cost interventions.[3,4] Yet the progress made on these goals shows remarkable heterogeneity – some countries have reduced child mortality, for example, by more than 80% from 1990-2010, while others have seen deaths in children under 5 rise.[1] Country-specific policies, programs, and funding have undoubtedly lead to differences in outcomes, yet in order to set more effective and targeted goals in the post-2015 era, an understanding of factors that consistently impact progress in health improvement across settings is needed.

Relationships between proximal determinants of health, such as childhood measles vaccination or uterotonic drugs to prevent hemorrhage, and improved outcomes have been well established across a range of settings.[5,6] Less well understood are the links between more distal social determinants of health – concepts like political will, female empowerment, and inequality. The connection between these factors and health has been established at individual and subnational scales, but the inherent difficulty in defining and measuring these more distal determinants has made it difficult to find consistent associations with health at the national level.

The Global Burden of Disease Study 2010 has produced estimates of death and disability for 291 conditions, 181 countries, by age and sex, from 1990-2010 – an unprecedented set of health estimates that allows researchers to explore relationships between national health outcomes and determinants of health.[1] Several social determinants of health have been measured and estimated in comparable and consistent ways and shown to be associated with health at the country level, including income per capita and average years of education.[7,8] Yet it is not just the average level of socioeconomic status (SES) that determines health; rather, health varies throughout the SES spectrum, resulting in what is termed a

'social gradient' in health.[9] Relative economic status, or economic inequality, has in particular been suggested as a determinant of health. The relationship between economic inequality and health has been explored in range of outcomes, including infant mortality, heart disease, depression, and suicide.[9-13] The existing evidence, however, is at small scales or is limited to selected subsets of countries because existing measures of economic inequality at the national scale are sparse and inconsistently generated.[14-16]

Economic inequality measures can be calculated from several sources, including income, expenditure, and asset ownership. Selection of the asset-based measure for this study was both pragmatic and rooted in theory. In practical terms, asset ownership has been shown to be more easily collected and to have lower recall bias than income or expenditure.[17,18] Income and expenditure may also fluctuate and be more volatile, whereas asset ownership is more consistent over time. The availability of household-level asset ownership information is widespread in nationally-representative surveys, more so than income or expenditure. Studies examining the relationship between a range of economic status measures and outcomes have ultimately found the measures to be consistent in estimating fertility, educational attainment, labor markets, and healthcare use.[19] My choice to examine an asset-based wealth measure was theoretically driven by the 'permanent income' hypothesis, which posits that wealth (here represented by asset ownership) better predicts long-term behavior than income or expenditure.[20]

The choice of statistical measure to capture economic inequality has been extensively explored, and in particular four properties that a measure should satisfy have been identified: anonymity, scale independence, population independence and the transfer principal.[21] Anonymity requires that a metric doesn't depend on which individuals own wealth. Scale independence arises when a metric remains constant if every individual's wealth is increased by the same percent. Population independence requires that the metric not be sensitive to how many people are in the population. Finally, the transfer principle states that transferring wealth from a wealthier to a poorer person leads to a decrease in inequality as measured by the metric. Common metrics include the Gini coefficient, the Atkinson, Theil, and Hoover indices, the ratio of levels of wealth owned by percentiles (i.e. 90^{th} to 10^{th}) and the percent of wealth owned by percentiles. Each of these has relative strengths and weaknesses and each is particularly

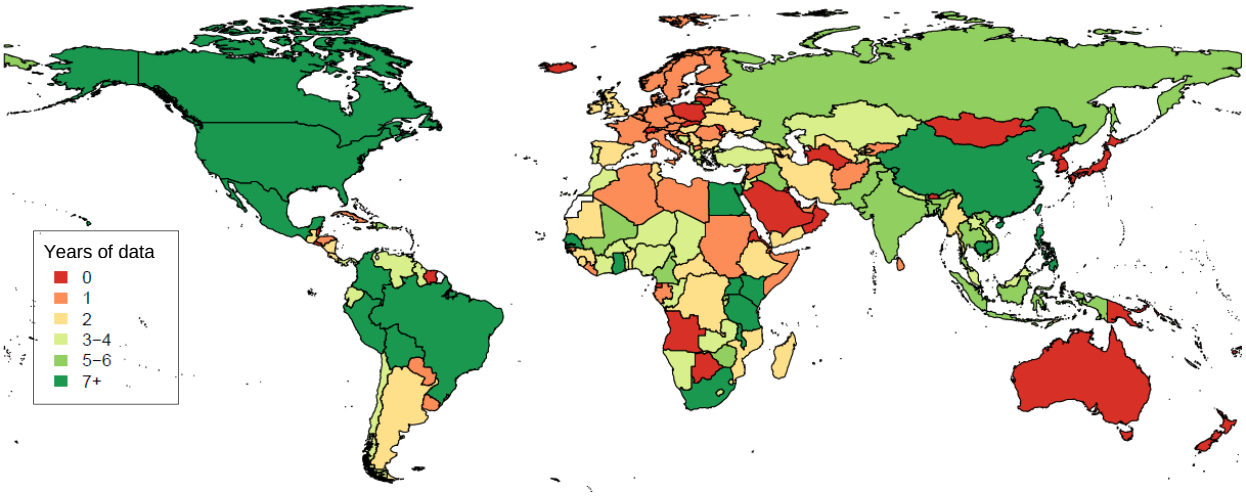
sensitive to inequality in an area of the distribution of wealth. A range of metrics were calculated and examined for this analysis. The Gini coefficient was selected because of its widespread use and familiarity, as well as satisfaction of the principals outlined above. [21] There are several shortcomings of the Gini coefficient, however, including limited ability for comparison across settings with very different average levels.[22] I thus also sought to examine whether the choice of inequality metric influenced the findings, so I selected an additional measure to replicate the analyses. The ideal alternate metric would differ from the Gini coefficient (i.e. have a correlation coefficient far from 1) and be sensitive to changes in areas of the wealth distribution other than the middle (as Gini is). The ratio of 90th to 10th percentiles was selected as an appropriate alternate metric because it fulfilled these criteria and is also relatively widely used.

Data

Potential surveys of use for this study were identified using the Institute for Health Metrics and Evaluation's Global Health Data Exchange.[23] Nearly 900 surveys were identified as nationally representative surveys collecting asset ownership information and with microdata (i.e. household or individual-level information) available. From these, sufficient and plausible wealth information could be extracted from 461 surveys in 140 countries over the time period 1980 to 2011. These studies include both well-established survey families such as Integrated Public Use Microdata Series (IPUMS) censuses, Demographic and Health Surveys (DHS), World Health Surveys (WHS), and Living Standards Measurement Surveys (LSMS), as well as one-time or single-country surveys such as the Iraq Family Health Survey or the National Income Dynamics Study from South Africa. The full data source list can be found in Annex Table 1.

Data covers 140 countries from all GBD regions and includes from 1 to 30 years of data for each country. The distribution and frequency of data sources is pictured in Figure 1, below.

Figure 1: Years of survey data used in inequality metric generation



Data on maternal and child mortality outcomes were estimates from the Global Burden of Disease Study 2010, the details of which are detailed elsewhere. [1]

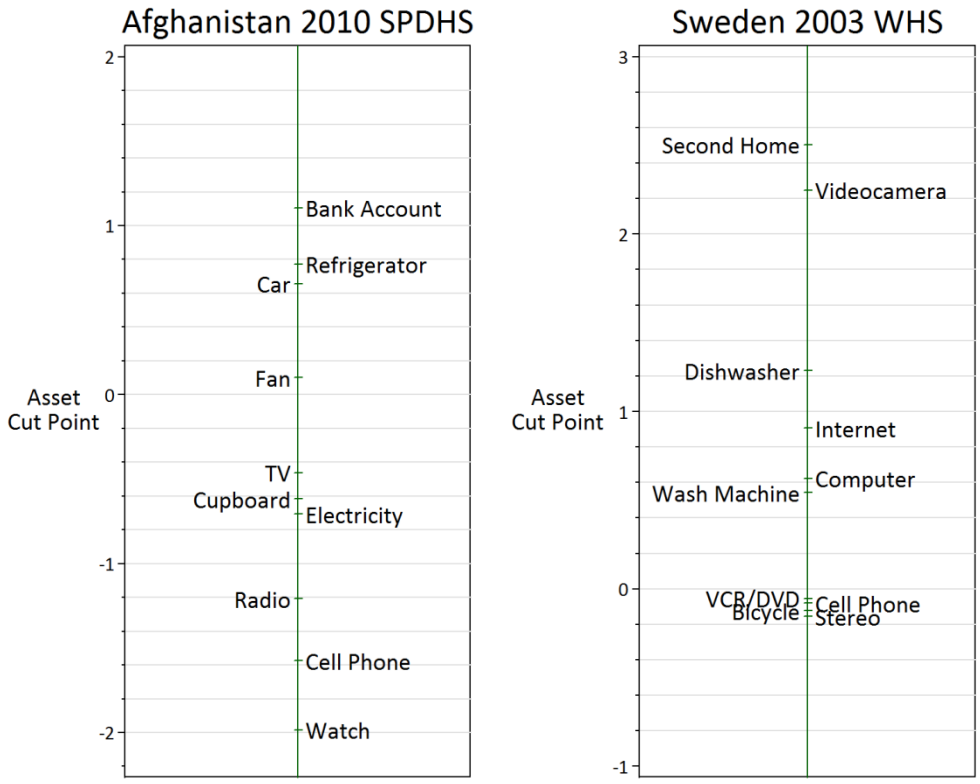
Methods

Construction of the asset-based wealth index

The wealth index was constructed in two broad steps: within-survey wealth estimation and conversion to an internationally- and time-comparable scale. To calculate the wealth index within each survey, I used the dichotomous hierarchical ordered probit (DIHOPIT) model established by Ferguson, Gakidou and others[24] and utilized previously by Cowling and Ngo.[25,26] The DIHOPIT model requires the input of two types of data: first, information about asset ownership, including goods such as televisions, dwelling characteristics such as floor material, and other measures such as access to electricity or running water (see Annex Table 2 for full list); secondly, information about the household, such as urbanicity, number of household members, and education levels within the household. The DIHOPIT model can be summarized as a 2-step Bayesian estimation process for household permanent income. In the first step, a probit regression of asset ownership and household characteristics is run and the prior of household wealth and 'asset cutpoints' are established. The prior estimate of household wealth is the prediction of wealth for a household based solely on characteristics (ignoring asset ownership) and is formed from the

coefficients on household characteristics. An asset cutpoint is defined as the coefficient on the asset and represents a value of wealth above which a household is more likely to own an item than not. In the example in Figure 2 below, a household in Afghanistan in 2010 would have a greater than 50% chance of owning a refrigerator if the household's wealth estimate was above 0.8 and a greater than 50% chance of owning a radio if the household's wealth was above -1.2.

Figure 2: Example asset cutpoint ladders



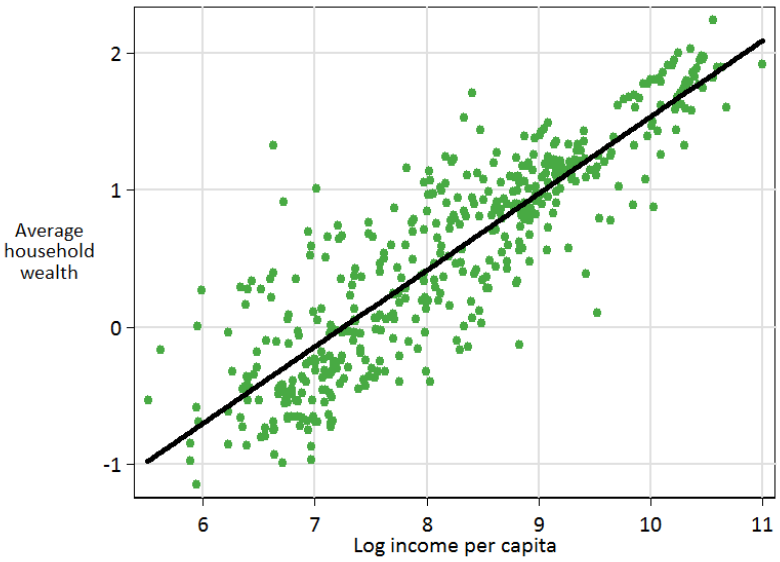
In the second step of the DIHOPIT model, the posterior is estimated in 100 iterations, combining the prior and asset cutpoints along with asset ownership information. This is done by generating 100 random estimates from a uniform distribution around the prior estimate, incorporating the uncertainty in the coefficients on household characteristics. I then calculate the probability of each of these draws representing that household's actual wealth value given what assets that house owns and what the cutpoint of each of those assets is.

Once the asset-based wealth index was created within each survey, the indices were made comparable across countries and time by identifying assets which could "anchor" the translation from within- to intra-survey scales. These "anchoring" assets must have low differential item functioning, i.e. behave similarly across place and time. The level of ownership need not be comparable (in one survey, 80% of the population may own an item while 20% own it elsewhere); what is important is that the rate of ownership either increases or decreases monotonically across wealth. In other words, as wealth increases, ownership should increase (or vice versa) in all countries and all years for an anchoring asset. These assets must also show up across several surveys and countries; this was defined as at least 5 surveys from at least 5 countries. Once these assets were identified, the average cutpoint value across all surveys was the global cutpoint value. Within each survey, I then ran a regression of global vs. survey-specific cutpoints for all anchoring assets present in that survey and used the results of the regression to linearly transform the survey to the global scale. A minimum of two anchoring assets were therefore necessary for a survey to be translated to the global scale.

Translation to International Dollar space

The wealth estimates are made on a unitless scale, and at the global scale household wealth estimates ranged from -7.3 to 6.0 across the more than 9 million households in the study. Many measures of inequality, however, require non-negative inputs. As such, I sought to transform the wealth estimates to a positive space. One option would be to shift all wealth estimates up by the lowest wealth estimate; this, however, can skew the resulting distribution for many inequality indices. Instead, I opted to transform the wealth estimates to international dollar space. To do so, I used a simple linear regression of the average wealth estimate for each survey against the corresponding average income per capita for that country and year. This linear relationship was deemed appropriate due to the very high correlation (R=.87) between average wealth and average income per capita; the regression coefficients were then used to transform all global wealth estimates to dollar space.

Figure 3: Relationship between average wealth and average log-transformed lag-distributed income per capita



Calculating inequality metrics

Within each survey, I created inequality metrics based on household's global wealth estimates in international dollar space. The *ineqdeco* program in STATA 11 was used to estimate Gini coefficients, Atkinson indices, the Theil index, the ratio of 90th to 10th percentiles, and other measures;[27] ultimately the Gini coefficient and ratio of 90th to 10th percentiles were used. Once inequality metrics were created, I used a combination linear regression and Gaussian process regression smoothing technique to create a time series of the metric. This smoothing tool did not incorporate any covariates to inform the time series nor did it borrow strength across countries, as regional trends in inequality did not *a priori* exist. The time series were therefore only created for the 140 countries for which there was at least 1 year of data.

Relationship between inequality and MDG-related health outcomes

Ultimately, the aim of this work was to add evidence to the debates around the relationship between health and inequality, and to quantify that relationship. In this thesis, I examined that relationship through

the lens of the Millennium Development Goals, namely reducing maternal mortality by 3/4 and reducing child mortality by 2/3. I did this in three ways, examining the relationship between 1990 inequality and MDG targets in terms of levels, rates of change, and thresholds of improvement. I examined both whether a relationship was significant once known determinants were controlled for, and further quantified the relationship through a counterfactual of a reduction in inequality of one standard deviation.

Specifically, I examined the following three relationships:

1. Inequality level in 1990 vs. whether or not a country was on track to meet the target as of 2010
2. Inequality level in 1990 vs. annualized percent change in the MDG target from 1990-2010
3. Inequality level in 1990 vs. MDG target level in 2010

Several explanatory covariates were examined. Income per capita was captured as log-transformed lag-distributed average income per capita. Education was measured by average years of education of women of reproductive age (15-49). HIV levels were measured as age-standardized HIV prevalence rates. Fertility was proxied by total fertility rate, the average number of children that would be born to a woman over her lifetime if she experienced the current age-specific fertility rates. Vaccination coverage was measured as proportion of children receiving three doses of Diphtheria-Tetanus-Pertussis vaccine (DTP3). Having a medical professional present at childbirth was estimated as the proportion of births with a skilled birth attendant; similarly in-facility delivery estimated what proportion of births occur in a hospital or health center. Finally, I examined a measure of health system access generated for the GBD 2010 Study, an aggregate of information on vaccination coverage, hospital beds per capita, in-facility delivery, and other metrics of intervention or prevention coverage. All covariates were produced by IHME.

A logit model was used for binary outcomes, initially controlling for 2010 levels of income per capita, average years of education of females of reproductive age, and HIV prevalence rates. For continuous outcomes, a similar linear regression was used, including additional covariates. Measures of average income, education, and HIV were included in all models because of the established relationship between these determinants and maternal and child health, and because previous work included these measures. Skilled birth attendance and in-facility delivery were insignificant in every relationship; the health system

access measure was highly collinear with other indicators and was thus excluded. Education and income per capita were also strongly correlated (R^2=.81), but both measures were informative to include in the models and exclusion would lead to biased estimates and poorer model fits. The inclusion of both covariates was also deemed appropriate because of their extensive combined use in GBD 2010 Study estimates. Total fertility rate was also closely related to education and LDI (R^2=.8), but was deemed appropriate to include given the established relationships between fertility and maternal and child mortality.[28] Vaccination coverage was associated with child mortality levels and trends and was included in the corresponding models. Inequality levels in 1990 and covariate levels in 2010 were used for all models.

Each regression was run for MDG 4 and MDG 5 and using both Gini coefficient and 90-10 ratio. I report the results as a significant or nonsignificant relationship, and further contextualize the results by creating a counterfactual where inequality in all countries is reduced by one standard deviation to see how results in 2010 would differ if the world had been more economically equal in 1990.

Ultimately, the following models were used:

1. Inequality level in 1990 vs. whether or not a country was on track to meet the target as of 2010

$$Acheivement \sim logit\ [\ \beta_{Ineq} * Inequality + \beta_{LDI} * LDI + \beta_{Educ} * Educ + \beta_{HIV} * HIV + C\ ]$$

2. Inequality level in 1990 vs. annualized percent change in the MDG target from 1990-2010

$$\%\ change\ MMR \sim \beta_{Ineq} * Inequality + \beta_{LDI} * LDI + \beta_{Educ} * Educ + \beta_{HIV} * HIV + \beta_{TFR} * TFR + C$$

$$\%\ change\ 5q0 \sim \beta_{Ineq} * Inequality + \beta_{LDI} * LDI + \beta_{Educ} * Educ + \beta_{HIV} * HIV + \beta_{TFR} * TFR + \beta_{DTP3} * DTP3 + C$$

3. Inequality level in 1990 vs. MDG target level in 2010

$$\ln(Level\ MMR) \sim \beta_{Ineq} * Inequality + \beta_{LDI} * LDI + \beta_{Educ} * Educ + \beta_{HIV} * HIV + C$$

$$\ln(Level\ 5q0) \sim \beta_{Ineq} * Inequality + \beta_{LDI} * LDI + \beta_{Educ} * Educ + \beta_{HIV} * HIV + \beta_{TFR} * TFR + \beta_{DTP3} * DTP3 + C$$

Findings

Inequality in 2010

What results from this analysis is a more complete and consistent picture of nation-level inequality worldwide than ever produced before. Inequality as estimated here is highest in southern Sub-Saharan Africa, India, and part of South America and lowest in parts of Western Europe and the Former USSR. Levels of inequality necessarily differ between inequality metrics; yet general patterns and rankings remain consistent (Spearman's ranking correlation 0.97 between the 90-10 ratio and Gini coefficient in 2010). The Gini coefficient for countries in 2010 ranged from a low of .17 in Montenegro to a high of .62 in Namibia. The ratio of 90^{th} to 10^{th} percentile of wealth ranged from 2.3 in Montenegro to 26.7 in Namibia. Results differ significantly from existing estimates such as those produced by the World Bank, the Organisation for Economic Co-Operation and Development, or the United Nations University World Institute for Development Economics Research group.[29-31] These differences are due to differences in data as well as the fact that these measures capture asset-based wealth inequalities, whereas existing measures often reflect income or expenditure differences.

Figure 4a: Gini coefficient in 2010

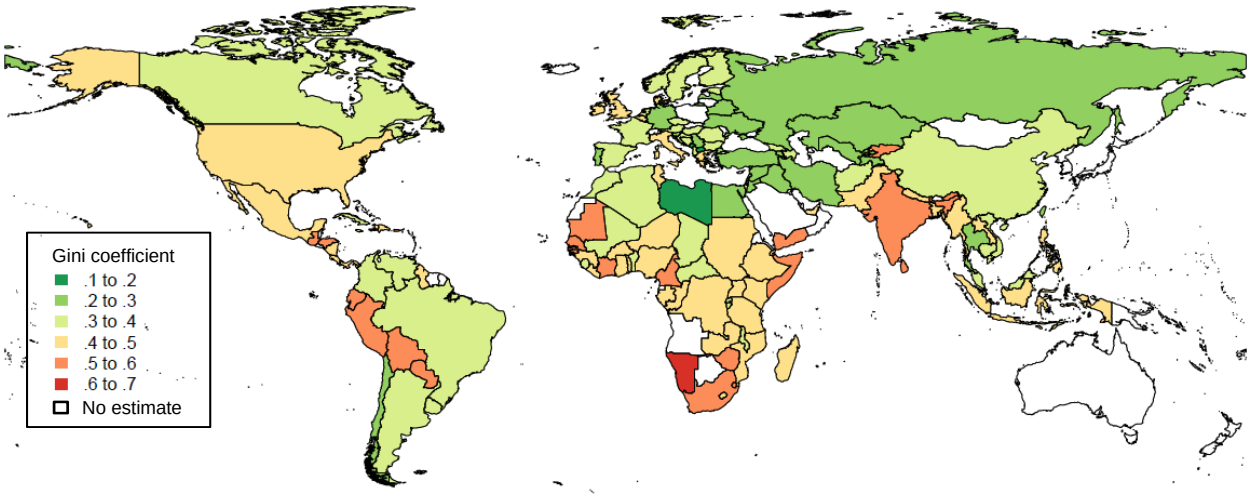
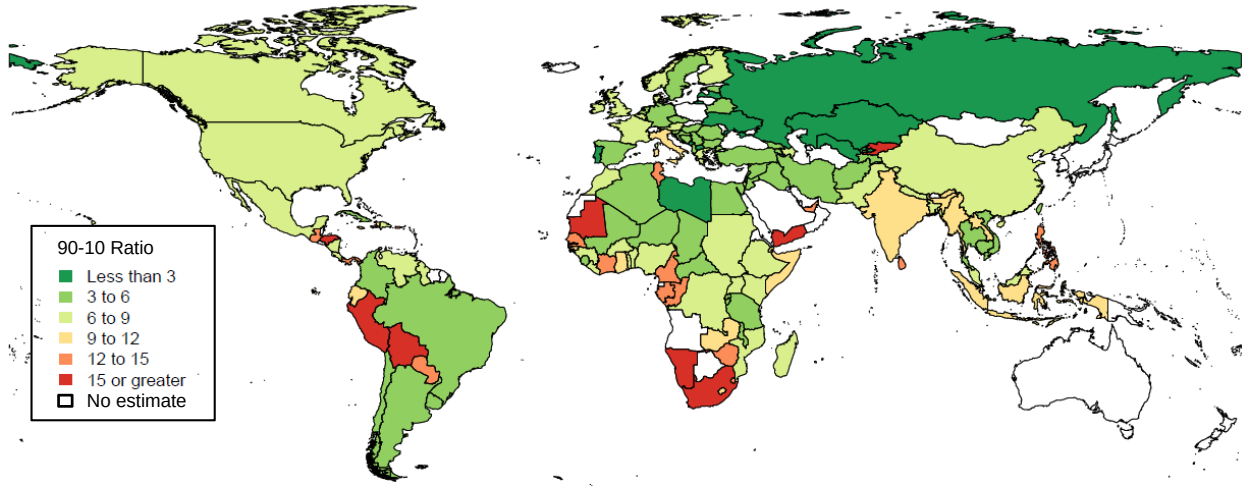


Figure 4b: Ratio of 90th to 10th percentile in 2010



Change 1990-2010

The time series produced here also allows for the examination of changes in inequality from 1990 to 2010. I defined a significant change in inequality as a change of one half of a standard deviation in the measure of interest, which translated to a change in Gini coefficient of 0.05 and a change in the ratio of

the 90th to 10th percentiles of wealth of 2.3. Based on the available data, 13 countries (9%) had a significant increase in inequality as measured by the Gini coefficient, while 30 countries (21%) had a significant decrease; the results for the 90-10 ratio suggest that 10 countries saw significant increases while 23 decreased inequality over the time period. The remaining countries either had insignificant changes or did not have sufficient data to detect a change.

Figure 5a: Gini coefficient change, 1990-2010

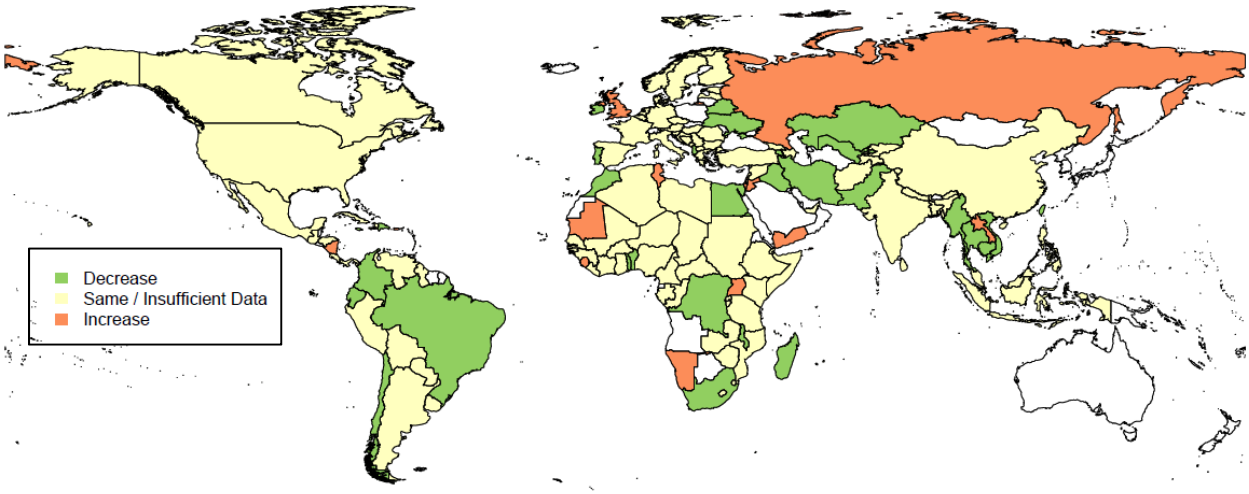
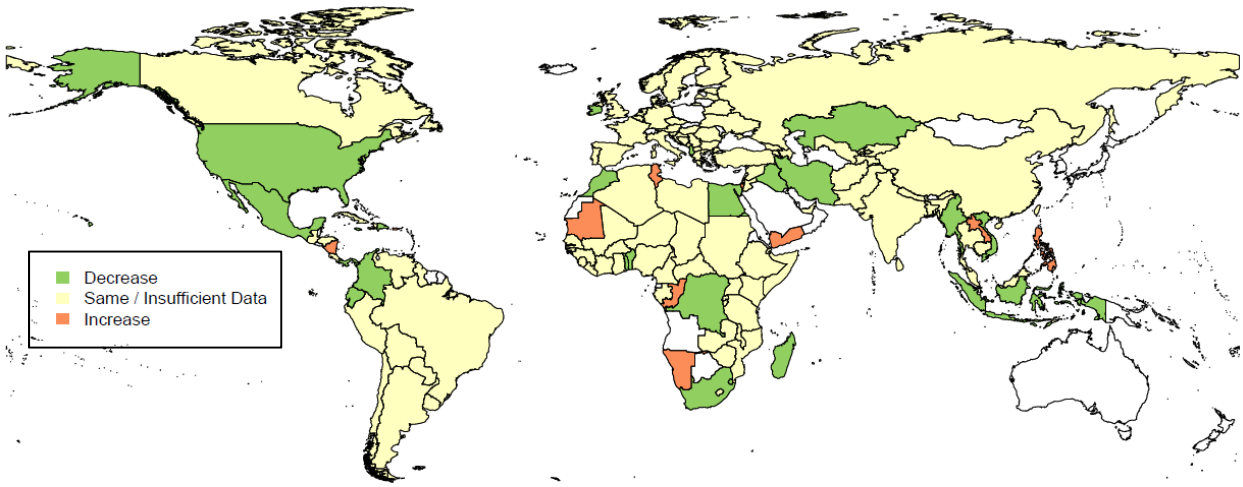


Figure 5b: 90-10 Ratio change, 1990-2010



MDG achievement

Results for both metrics of inequality and for MDGs 4 and 5 are summarized in Table 1, below.

Table 1: Results of regressions between inequality and MDG outcomes

Outcome	MDG	Initial value	With Gini .1 reduction	With 90-10 ratio 5.1 reduction
MDG achievement: % on track	**5**	7.25%	13.62%**	17.38%
	4	24.64%	32.10%*	31.58%
Target rate change: Annualized % change 90-10	**5**	-2.22%	-2.85%**	-2.68%**
	4	-3.50%	-3.84%**	-3.74%**
Target 2010 level: log MMR & 5q0	**5**	188.5	134.5***	129.1***
	4	4.48	3.93**	3.82***

** Significant at the .1 level; ** Significant at the .05 level; *** Significant at the <.01 level*

Firstly, I examined thresholds of improvement as the relationship between inequality in 1990 and whether or not a country was on track to achieve the MDG target as of 2010. Inequality in 1990 had a significant negative effect at the .05 level on the likelihood of a country being on track to meet MDG 5. Initial likelihood of being on track to meet MDG 5 was 7.2% (10 countries); given a reduction in 1990 Gini coefficient of 0.1, I would expect that number to nearly double (a chance of success of 13.6%, or 20 countries). Though the results were not as statistically significant nor the counterfactual scenario so striking, the results for MDG 4 and Gini coefficient suggest that the number of countries on track to meet MDG 4 would be significantly greater (30% more would be on track) if inequality were one standard deviation lower in 1990. This was the one set of analyses which had different findings for the two inequality metrics; the ratio of 90^{th} to 10^{th} percentile failed to have a significant relationship while Gini coefficient did. This may be because of a relatively small sample size (only 10 countries were on track to meet MDG 5 and 34 on track to meet MDG 4), or may suggest that child and maternal mortality improvements are more sensitive to equity in the middle of the wealth distribution (as is captured by the Gini coefficient) rather than at the extremes, as the ratio of 90^{th} to 10^{th} percentiles captures.

The second set of analyses examined rates of change via a comparison of inequality in 1990 as compared to annualized percent change in the MDG target from 1990-2010. The relationship between inequality and rate of change was significant at the .05 level for both MDGs and for both outcomes measured. The counterfactual scenario suggests that decreases in inequality would have led to relative increases in rates of decline (faster improvement) of 7 to 28%. These counterfactual rates can be applied to GBD 2010 death estimates, translating to 58-65 thousand maternal deaths that would have been averted in 2010 if inequality had been on standard deviation lower in 1990.

The third set of analyses examined levels of MDG target outcome performance through the relationship between inequality in 1990 and MDG target outcome level in 2010. Outcomes were log transformed due to the distribution of outcome levels. The strongest relationships were found in this set of regressions, for both MDGs and for both inequality metrics. More unequal countries had higher maternal and child mortality, even after controlling for average economic levels and other known determinants. Once again, significant reductions in current levels of mortality would be expected given decreased inequality in 1990.

Interpretation

Summary of findings

A number of important points emerge from these results, three of which I wish to highlight. First, inequality in 1990 is a significant predictor of health outcomes as measured by levels, rates of change, and thresholds of improvement in both of the MDG targets. Interestingly, inequality (as measured by the Gini coefficient) is the only significant predictor of whether or not a country is on track to achieve the MDG targets; LDI, education, and HIV prevalence (in 2010) are all non-significant in the target achievement model. Second, the choice of inequality metric does not change these findings, with the exception of significance in the model of countries on track to meet the MDG targets. Similarly, the magnitude of expected improvement given a counterfactual reduction in 1990 inequality is comparable for both inequality metrics across models. Third, a stronger and larger relationship with inequality (as measured by the counterfactual) is found with maternal mortality as compared with child mortality across each set of models.

The consistent and positive relationship between inequality and health as measured by the MDG targets suggest that more economically equal countries are more likely to meet health-related targets, to have faster progress in improving health, and to have better health outcomes. Why might this relationship be? At the individual level, a biological stress-related hypothesis holds that the perception of deprivation (the perception of unequal distributions) between an individual and the society around them leads to stress, increased inflammatory response, increased blood pressure, and thus ultimately worse health outcomes.[32,33] This stress response may have merit, but would be surprising to observe and capture within national averages examined here

Alternately, wealth-based inequality may serve as a proxy for redistributive policies and resources available to more deprived or impoverished groups. Groups may have relatively equal asset ownership because redistributive taxes allow them to purchase similar goods, or freely-available social services such as education and healthcare enable them to avoid spending shocks and purchase goods rather than spend wealth on these services.[34] Conversely, redistributive policies and social services may emerge from more equal places to begin with; people may be more willing to fund a common good when they're more likely to be able to utilize it. This is supported by theories relating inequality and social cohesion, which state that societies with greater inequality lack cohesion, group membership, and have disagreement. This in turn prevents them from establishing policies and institutions that would be beneficial to health, ultimately leading to poorer health outcomes.[35]

Similar data to that used here has also been used to produce metrics which capture poverty rather than inequality. A measure such as the one produced here should be combined with estimates of absolute poverty for a more complete picture of economic status. This is particularly valuable in light of the link between extreme poverty and inequality: a full third of the remarkable progress in achieving MDG 1 (halving extreme poverty) has been attributed to increasing economic equality within countries (the other 2/3 due to growth).[36] Studies have suggested that a 1% increase in incomes cut poverty by 0.6% in the most unequal countries but by 4.3% in the most equal ones.[37] Given the established relationship between poverty and ill health, this may also be why lower inequality is associated with improved health outcomes.

The counterfactual scenarios suggest that substantial health improvement would be expected with reduced inequality. This is an argument for redistributive and equality-promoting policies to reduce national-level inequality and improve health, but any conclusions drawn between inequality and health are necessarily associative and not causal. There is still valuable insight to be drawn from identifying such associations, however, and this can add evidence to future debates regarding causal impacts of inequality on health.

Despite these findings, substantial variance in health outcomes, improvements, and rates of change remain unexplained. In another theoretical counterfactual, reducing inequality completely still fails to improve health completely – for example, even with a Gini coefficient of 0 for all countries (perfectly equitable wealth distribution), only 52% of countries would be on target to meet MDG 5 given their current income per capita, education, and other health resource and intervention coverage. Reducing inequality alone, then, is obviously not sufficient to promote excellent health.

Limitations

Though I have attempted to identify more data sources than ever used before, I still have gaps in estimation, including countries without any data and countries with only one or two years of estimates. Estimates of change in inequality over time are particularly limited by this issue. Though I have attempted to identify and remove non-representative studies or studies with implausible estimates, the quality of these results are only as good as the quality of data used. Each measure of inequality computed also has its own strengths and limitations, but the consistency of findings across metrics suggests that these metric-based limitations are minor.

A more nuanced limitation is also inherent in the consideration of assets as a measure of more permanent wealth – though I chose to examine what I consider to be liquid assets, in parts of the world with poor banking systems, these goods may in fact represent more illiquid assets. In parts of rural India where it may take days to reach a bank, for example, a family may buy livestock as an investment, whereas in the United States a similar family with excess money would put it into a CD. I may thus have captured different sorts of wealth in different places. By failing to capture the totality of wealth in

investments, I may underestimate inequality in high-income places relative to those where goods represent the majority of wealth.

Finally, this study captures only one level of inequality - national - and may mask more significant subnational unequal distributions of wealth. Given the hypotheses of a biological stress-related impact of inequality on health, these more local unequal distributions may in fact be more important in determining health outcomes.

Future work

This is the largest set of consistently-generated estimates of economic inequality to date and affords a number of opportunities to explore the relationship between inequality and health. Metrics such as these can in particular be combined with information from the GBD to examine whether the relationship between inequality and infant mortality, depression, suicide, heart disease, or any number of other outcomes exists at the national level.

An integral part of the GBD Study is the inclusion of informative covariates for mortality and morbidity estimation. If consistent relationships are found with a range of health outcomes and inequality, this metric could serve to be an important covariate for future iterations of the GBD. The estimates of inequality could also be useful in setting targets for the post-2015 era; accounting for current levels of inequality and other determinants of health can help to set realistic but high goals for progress.

The idea that inequality impacts health is not a new one; this study, however, is one of the first to demonstrate that relationship consistently at the national level. In addition to providing new insight into the relationship between distal determinants and health outcomes, this work suggests that a shift in focus would benefit global health efforts and that reducing economic inequality could be a key for improving health for populations worldwide.

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Annex Table 1: Datasource List

Country	Year	Survey
Afghanistan	2010	Special Demographic and Health Survey
Albania	2002	Living Standards Measurement Study
Albania	2008	Demographic and Health Surveys
Algeria	1992	Pan-Arab Project for Child Development (PAPCHILD)
Argentina	1991	Census
Argentina	2001	Census
Armenia	2005	Demographic and Health Surveys
Armenia	2010	Demographic and Health Surveys
Austria	2003	World Health Survey
Azerbaijan	1995	Living Standards Measurement Study
Azerbaijan	2006	Demographic and Health Surveys
Bangladesh	2001	Special Demographic and Health Survey
Bangladesh	2003	World Health Survey
Bangladesh	2004	Demographic and Health Surveys
Bangladesh	2006	Multiple Indicator Cluster Survey Wave 3
Bangladesh	2007	Demographic and Health Surveys
Bangladesh	2011	Demographic and Health Surveys
Belarus	1999	Census
Belarus	2005	Multiple Indicator Cluster Survey Wave 3
Belgium	2003	World Health Survey
Benin	2001	Demographic and Health Surveys
Benin	2006	Demographic and Health Surveys
Bolivia	1992	Census
Bolivia	1993	Demographic and Health Surveys
Bolivia	1998	Demographic and Health Surveys
Bolivia	2001	Census
Bolivia	2003	Demographic and Health Surveys
Bolivia	2008	Demographic and Health Surveys
Bosnia and Herzegovina	2001	Living Standards Measurement Study
Bosnia and Herzegovina	2003	World Health Survey
Brazil	1980	Census
Brazil	1991	Census
Brazil	1996	Living Standards Measurement Study
Brazil	2000	Census
Brazil	2003	World Health Survey
Brazil	2008	Consumer Expenditure Survey
Bulgaria	1995	Living Standards Measurement Study
Bulgaria	2001	Living Standards Measurement Study
Burkina Faso	2002	World Health Survey
Burkina Faso	2006	Multiple Indicator Cluster Survey Wave 3
Burkina Faso	2010	Demographic and Health Surveys
Burundi	2000	Multiple Indicator Cluster Survey Wave 2
Burundi	2005	Multiple Indicator Cluster Survey Wave 3
Burundi	2010	Demographic and Health Surveys
Cambodia	1996	Cambodia Socioeconomic Survey
Cambodia	1997	Cambodia Socioeconomic Survey
Cambodia	2000	Demographic and Health Surveys
Cambodia	2005	Demographic and Health Surveys
Cambodia	2007	Cambodia Socioeconomic Survey
Cambodia	2008	Census
Cambodia	2010	Demographic and Health Surveys
Cameroon	1991	Demographic and Health Surveys
Cameroon	1998	Demographic and Health Surveys

Cameroon	2004	Demographic and Health Surveys
Cameroon	2006	Multiple Indicator Cluster Survey Wave 3
Cameroon	2011	Demographic and Health Surveys
Canada	1982	Family Expenditure Survey
Canada	1997	Student Health Survey if survey
Canada	1998	Student Health Survey if survey
Canada	1999	Student Health Survey if survey
Canada	2000	Student Health Survey if survey
Canada	2001	Student Health Survey if survey
Canada	2002	Student Health Survey if survey
Canada	2003	Student Health Survey if survey
Canada	2004	Student Health Survey if survey
Canada	2005	Student Health Survey if survey
Canada	2006	Student Health Survey if survey
Canada	2007	Student Health Survey if survey
Canada	2008	Student Health Survey if survey
Canada	2009	Student Health Survey if survey
Central African Republic	2000	Multiple Indicator Cluster Survey Wave 2
Central African Republic	2006	Multiple Indicator Cluster Survey Wave 3
Chad	1996	Demographic and Health Surveys
Chad	2003	World Health Survey
Chad	2004	Demographic and Health Surveys
Chile	1982	Census
Chile	1992	Census
Chile	2002	Census
China	1989	China Health and Nutrition Survey
China	1991	China Health and Nutrition Survey
China	1993	China Health and Nutrition Survey
China	1997	China Health and Nutrition Survey
China	2000	China Health and Nutrition Survey
China	2002	World Health Survey
China	2004	China Health and Nutrition Survey
China	2006	China Health and Nutrition Survey
China	2009	China Health and Nutrition Survey
Colombia	1985	Census
Colombia	1990	Demographic and Health Surveys
Colombia	1993	Census
Colombia	1995	Demographic and Health Surveys
Colombia	2000	Demographic and Health Surveys
Colombia	2004	Demographic and Health Surveys
Colombia	2005	Census
Colombia	2009	Demographic and Health Surveys
Comoros	1996	Demographic and Health Surveys
Comoros	2000	Multiple Indicator Cluster Survey Wave 2
Comoros	2003	World Health Survey
Congo	2003	World Health Survey
Congo	2005	Demographic and Health Surveys
Congo	2009	AIDS Indicator Surveys
Costa Rica	1984	Census
Costa Rica	2000	Census
Croatia	2003	World Health Survey
Cuba	2000	Census
Czech Republic	2002	World Health Survey
Côte d'Ivoire	1998	Demographic and Health Surveys
Côte d'Ivoire	2003	World Health Survey
Côte d'Ivoire	2006	Multiple Indicator Cluster Survey Wave 3

Democratic Republic of the Con	2001	Multiple Indicator Cluster Survey Wave 2
Democratic Republic of the Con	2007	Demographic and Health Surveys
Denmark	2003	World Health Survey
Djibouti	2006	Multiple Indicator Cluster Survey Wave 3
Dominican Republic	1996	Demographic and Health Surveys
Dominican Republic	2002	Demographic and Health Surveys
Dominican Republic	2003	World Health Survey
Dominican Republic	2007	Demographic and Health Surveys
Dominican Republic	2007	Special Demographic and Health Survey
Ecuador	1990	Census
Ecuador	2001	Census
Ecuador	2003	World Health Survey
Egypt	1991	Pan-Arab Project for Child Development (PAPCHILD)
Egypt	1992	Demographic and Health Surveys
Egypt	1995	Demographic and Health Surveys
Egypt	1997	Integrated Household Survey
Egypt	2000	Demographic and Health Surveys
Egypt	2003	Interim DHS Survey
Egypt	2005	Demographic and Health Surveys
Egypt	2006	Census
Egypt	2008	Demographic and Health Surveys
Estonia	2003	World Health Survey
Ethiopia	2003	World Health Survey
Ethiopia	2010	Demographic and Health Surveys
Finland	2004	World Health Survey
France	2003	World Health Survey
Gabon	2000	Demographic and Health Surveys
Georgia	2003	World Health Survey
Georgia	2005	Multiple Indicator Cluster Survey Wave 3
Germany	2004	World Health Survey
Ghana	1993	Demographic and Health Surveys
Ghana	1998	Demographic and Health Surveys
Ghana	2003	Demographic and Health Surveys
Ghana	2003	World Health Survey
Ghana	2006	Multiple Indicator Cluster Survey Wave 3
Ghana	2008	Demographic and Health Surveys
Greece	2003	World Health Survey
Guatemala	1998	Interim DHS Survey
Guatemala	2003	World Health Survey
Guinea	1999	Demographic and Health Surveys
Guinea	2005	Demographic and Health Surveys
Guinea-Bissau	2006	Multiple Indicator Cluster Survey Wave 3
Guyana	2005	AIDS Indicator Surveys
Guyana	2006	Multiple Indicator Cluster Survey Wave 3
Guyana	2009	Demographic and Health Surveys
Haiti	1994	Demographic and Health Surveys
Haiti	2000	Demographic and Health Surveys
Haiti	2005	Demographic and Health Surveys
Honduras	2005	Demographic and Health Surveys
Hungary	2001	Census
Hungary	2003	World Health Survey
India	1992	Demographic and Health Surveys
India	1998	Demographic and Health Surveys
India	2003	World Health Survey
India	2005	Demographic and Health Surveys
India	2007	District Level Household Survey

Indonesia	1994	Demographic and Health Surveys
Indonesia	1997	Demographic and Health Surveys
Indonesia	2002	Demographic and Health Surveys
Indonesia	2005	National Socio-Economic Household Survey (SUSENAS)
Indonesia	2007	Demographic and Health Surveys
Iran	2000	Demographic and Health Surveys
Iran	2006	Census
Iraq	1997	Census
Iraq	2006	Iraq Family Health Survey
Iraq	2006	Multiple Indicator Cluster Survey Wave 3
Iraq	2011	Multiple Indicator Cluster Survey Wave 4
Ireland	1991	Census
Ireland	2003	World Health Survey
Israel	1983	Census
Israel	1995	Census
Israel	2003	World Health Survey
Italy	2003	World Health Survey
Jamaica	1991	Census
Jamaica	1997	Living Standards Measurement Study
Jamaica	2001	Census
Jordan	1997	Demographic and Health Surveys
Jordan	2004	Census
Jordan	2007	Demographic and Health Surveys
Jordan	2009	Interim DHS Survey
Kazakhstan	1995	Demographic and Health Surveys
Kazakhstan	2002	World Health Survey
Kazakhstan	2006	Multiple Indicator Cluster Survey Wave 3
Kenya	1988	Demographic and Health Surveys
Kenya	1993	Demographic and Health Surveys
Kenya	1998	Demographic and Health Surveys
Kenya	1999	Census
Kenya	2000	Multiple Indicator Cluster Survey Wave 2
Kenya	2003	Demographic and Health Surveys
Kenya	2004	World Health Survey
Kenya	2008	Demographic and Health Surveys
Kyrgyzstan	2005	Multiple Indicator Cluster Survey Wave 3
Laos	2000	Multiple Indicator Cluster Survey Wave 2
Laos	2003	World Health Survey
Laos	2006	Multiple Indicator Cluster Survey Wave 3
Latvia	2003	World Health Survey
Lebanon	1996	Pan-Arab Project for Child Development (PAPCHILD)
Lebanon	2004	Pan-Arab Project for Family Health (PAPFAM)
Lesotho	2000	Multiple Indicator Cluster Survey Wave 2
Lesotho	2004	Demographic and Health Surveys
Lesotho	2009	Demographic and Health Surveys
Liberia	2006	Demographic and Health Surveys
Libya	1995	Pan-Arab Project for Child Development (PAPCHILD)
Luxembourg	2003	World Health Survey
Macedonia	2005	Multiple Indicator Cluster Survey Wave 3
Madagascar	2003	Demographic and Health Surveys
Madagascar	2008	Demographic and Health Surveys
Malawi	1992	Demographic and Health Surveys
Malawi	1998	Census
Malawi	2003	World Health Survey
Malawi	2004	Demographic and Health Surveys
Malawi	2006	Multiple Indicator Cluster Survey Wave 3

Malawi	2008	Census
Malawi	2010	Demographic and Health Surveys
Malaysia	1980	Census
Malaysia	1991	Census
Malaysia	2000	Census
Malaysia	2003	World Health Survey
Maldives	2009	Demographic and Health Surveys
Mali	1995	Demographic and Health Surveys
Mali	1998	Census
Mali	2001	Demographic and Health Surveys
Mali	2003	World Health Survey
Mali	2006	Demographic and Health Surveys
Mauritania	2003	World Health Survey
Mauritania	2007	Multiple Indicator Cluster Survey Wave 3
Mauritius	2003	World Health Survey
Mexico	1989	National Household Income and Expenditure Survey (ENIGH)
Mexico	1990	Census
Mexico	1992	National Household Income and Expenditure Survey (ENIGH)
Mexico	1994	National Household Income and Expenditure Survey (ENIGH)
Mexico	1995	Census
Mexico	1996	National Household Income and Expenditure Survey (ENIGH)
Mexico	2000	Census
Mexico	2000	National Household Income and Expenditure Survey (ENIGH)
Mexico	2002	National Household Income and Expenditure Survey (ENIGH)
Mexico	2002	World Health Survey
Mexico	2004	National Household Income and Expenditure Survey (ENIGH)
Mexico	2005	Census
Mexico	2005	National Household Income and Expenditure Survey (ENIGH)
Mexico	2006	National Household Income and Expenditure Survey (ENIGH)
Montenegro	2005	Multiple Indicator Cluster Survey Wave 3
Morocco	1992	Demographic and Health Surveys
Morocco	1997	Pan-Arab Project for Child Development (PAPCHILD)
Morocco	2003	Demographic and Health Surveys
Morocco	2003	World Health Survey
Mozambique	1997	Demographic and Health Surveys
Mozambique	2003	Demographic and Health Surveys
Myanmar	2000	Multiple Indicator Cluster Survey Wave 2
Myanmar	2003	World Health Survey
Namibia	1992	Demographic and Health Surveys
Namibia	2000	Demographic and Health Surveys
Namibia	2003	World Health Survey
Namibia	2006	Demographic and Health Surveys
Nepal	1996	Demographic and Health Surveys
Nepal	2003	World Health Survey
Nepal	2006	Demographic and Health Surveys
Nepal	2011	Demographic and Health Surveys
Netherlands	2004	World Health Survey
Nicaragua	1997	Demographic and Health Surveys
Nicaragua	2001	Demographic and Health Surveys
Niger	1998	Demographic and Health Surveys
Niger	2000	Multiple Indicator Cluster Survey Wave 2
Niger	2006	Demographic and Health Surveys
Nigeria	2003	Demographic and Health Surveys
Nigeria	2007	Multiple Indicator Cluster Survey Wave 3
Nigeria	2008	Demographic and Health Surveys
Nigeria	2010	Malaria Indicator Surveys

Norway	2003	World Health Survey
Pakistan	1999	Household Income and Expenditure Survyes
Pakistan	2003	World Health Survey
Pakistan	2005	Household Income and Expenditure Survyes
Pakistan	2006	Demographic and Health Surveys
Pakistan	2006	Household Income and Expenditure Survyes
Pakistan	2008	Household Income and Expenditure Survyes
Palestine	1997	Census
Palestine	2007	Census
Panama	1980	Census
Panama	1990	Census
Panama	2000	Census
Paraguay	2002	World Health Survey
Peru	1991	Demographic and Health Surveys
Peru	1993	Census
Peru	1996	Demographic and Health Surveys
Peru	2000	Demographic and Health Surveys
Peru	2004	Demographic and Health Surveys
Peru	2007	Census
Peru	2007	Demographic and Health Surveys
Philippines	1990	Census
Philippines	1991	Family Income and Expenditure Survey
Philippines	1993	Interim DHS Survey
Philippines	1994	Family Income and Expenditure Survey
Philippines	1997	Family Income and Expenditure Survey
Philippines	1998	Demographic and Health Surveys
Philippines	1999	Multiple Indicator Cluster Survey Wave 2
Philippines	2000	Census
Philippines	2003	Demographic and Health Surveys
Philippines	2003	Family Income and Expenditure Survey
Philippines	2003	World Health Survey
Philippines	2006	Family Income and Expenditure Survey
Philippines	2008	Demographic and Health Surveys
Portugal	1981	Census
Portugal	1991	Census
Portugal	2001	Census
Puerto Rico	1980	Census
Puerto Rico	1990	Census
Puerto Rico	2000	Census
Puerto Rico	2005	Census
Romania	1994	Living Standards Measurement Study
Russia	1992	Russia Longitudinal Monitoring Survey
Russia	2000	Russia Longitudinal Monitoring Survey
Russia	2001	Russia Longitudinal Monitoring Survey
Russia	2002	Russia Longitudinal Monitoring Survey
Russia	2003	World Health Survey
Rwanda	1991	Census
Rwanda	1992	Demographic and Health Surveys
Rwanda	2000	Multiple Indicator Cluster Survey Wave 2
Rwanda	2002	Census
Rwanda	2010	Demographic and Health Surveys
Saint Lucia	1991	Census
Senegal	1988	Census
Senegal	1992	Demographic and Health Surveys
Senegal	2000	Multiple Indicator Cluster Survey Wave 2
Senegal	2002	Census

Senegal	2003	World Health Survey
Senegal	2005	Demographic and Health Surveys
Senegal	2010	Demographic and Health Surveys
Serbia	2005	Multiple Indicator Cluster Survey Wave 3
Serbia	2007	Living Standards Measurement Study
Sierra Leone	2004	Census
Sierra Leone	2008	Demographic and Health Surveys
Slovenia	2003	World Health Survey
Somalia	2006	Multiple Indicator Cluster Survey Wave 3
South Africa	1993	Living Standards Measurement Study
South Africa	1996	Census
South Africa	1998	Demographic and Health Surveys
South Africa	2001	Census
South Africa	2002	World Health Survey
South Africa	2007	Census
South Africa	2008	National Income Dynamics Study
Spain	2001	Census
Spain	2002	World Health Survey
Sri Lanka	2003	World Health Survey
Sudan	1992	Pan-Arab Project for Child Development (PAPCHILD)
Swaziland	2000	Multiple Indicator Cluster Survey Wave 2
Swaziland	2003	World Health Survey
Swaziland	2006	Demographic and Health Surveys
Sweden	2003	World Health Survey
Syria	1993	Pan-Arab Project for Child Development (PAPCHILD)
São Tomé and Príncipe	2000	Multiple Indicator Cluster Survey Wave 2
São Tomé and Príncipe	2008	Demographic and Health Surveys
Taiwan	1980	Family Income and Expenditure Survey
Taiwan	1981	Family Income and Expenditure Survey
Taiwan	1982	Family Income and Expenditure Survey
Taiwan	1983	Family Income and Expenditure Survey
Taiwan	1984	Family Income and Expenditure Survey
Taiwan	1985	Family Income and Expenditure Survey
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Taiwan	2004	Family Income and Expenditure Survey
Taiwan	2005	Family Income and Expenditure Survey
Taiwan	2006	Family Income and Expenditure Survey
Taiwan	2007	Family Income and Expenditure Survey
Taiwan	2008	Family Income and Expenditure Survey

Taiwan	2009	Family Income and Expenditure Survey
Tajikistan	1999	Living Standards Measurement Study
Tajikistan	2000	Multiple Indicator Cluster Survey Wave 2
Tajikistan	2003	Living Standards Measurement Study
Tajikistan	2005	Multiple Indicator Cluster Survey Wave 3
Tanzania	1988	Census
Tanzania	1991	Demographic and Health Surveys
Tanzania	1991	Living Standards Measurement Study
Tanzania	1996	Demographic and Health Surveys
Tanzania	2004	Demographic and Health Surveys
Tanzania	2007	AIDS Indicator Surveys
Tanzania	2009	Demographic and Health Surveys
Thailand	1980	Census
Thailand	1987	Demographic and Health Surveys
Thailand	1990	Census
Thailand	2000	Census
Thailand	2005	Multiple Indicator Cluster Survey Wave 3
The Gambia	2005	Multiple Indicator Cluster Survey Wave 3
Timor-Leste	2001	Living Standards Measurement Study
Timor-Leste	2009	Demographic and Health Surveys
Togo	1998	Demographic and Health Surveys
Togo	2000	Multiple Indicator Cluster Survey Wave 2
Togo	2006	Multiple Indicator Cluster Survey Wave 3
Tunisia	1994	Pan-Arab Project for Child Development (PAPCHILD)
Tunisia	2003	World Health Survey
Turkey	1993	Demographic and Health Surveys
Turkey	1998	Demographic and Health Surveys
Turkey	2003	Demographic and Health Surveys
Turkey	2003	World Health Survey
Uganda	1995	Demographic and Health Surveys
Uganda	2002	Census
Uganda	2002	Uganda National Household Survey
Uganda	2006	Demographic and Health Surveys
Uganda	2006	Uganda National Household Survey
Uganda	2011	Demographic and Health Surveys
Uganda	2011	AIDS Indicator Surveys
Ukraine	2002	World Health Survey
Ukraine	2007	Demographic and Health Surveys
United Arab Emirates	2003	World Health Survey
United Kingdom	1991	Census
United Kingdom	2004	World Health Survey
United States	1980	Census
United States	1990	Census
United States	1999	Panel Study of Income Dynamics
United States	2003	Panel Study of Income Dynamics
United States	2005	Panel Study of Income Dynamics
United States	2007	Panel Study of Income Dynamics
Uruguay	2002	World Health Survey
Uzbekistan	2002	Special Demographic and Health Survey
Uzbekistan	2006	Multiple Indicator Cluster Survey Wave 3
Venezuela	1981	Census
Venezuela	1990	Census
Venezuela	2000	Multiple Indicator Cluster Survey Wave 2
Venezuela	2001	Census
Vietnam	1997	Demographic and Health Surveys
Vietnam	2000	Multiple Indicator Cluster Survey Wave 2

Vietnam	2002	Demographic and Health Surveys
Vietnam	2002	World Health Survey
Vietnam	2005	AIDS Indicator Surveys
Vietnam	2006	Multiple Indicator Cluster Survey Wave 3
Yemen	1991	Pan-Arab Project for Child Development (PAPCHILD)
Yemen	2006	Multiple Indicator Cluster Survey Wave 3
Zambia	1992	Demographic and Health Surveys
Zambia	1996	Demographic and Health Surveys
Zambia	2001	Demographic and Health Surveys
Zambia	2007	Demographic and Health Surveys
Zimbabwe	1994	Demographic and Health Surveys
Zimbabwe	1999	Demographic and Health Surveys
Zimbabwe	2003	World Health Survey
Zimbabwe	2005	Demographic and Health Surveys
Zimbabwe	2010	Demographic and Health Surveys

Annex Table 2: List of goods extracted from surveys

Goods
Air conditioner
Animal
Animal cart
Bank account
Bed
Bench
Bicycle
Blender
Boat
Bucket
Camera
Car
Cart
Cell phone
Chair
Clock
Computer
Cookfuel type
Cooking location
Couch
Dishwasher
Dresser
Drinkwater source
Electric radiator
Electricity
Family owns the home
Floor material
Freezer
Gas stove
Generator
Internet
Iron
Kerosene stove
Land in hectares
Land phone
Microwave
Moped
Motor boat
Motorcycle
Number of rooms for sleeping
Plough
Radio
Refrigerator
Roof material
Satellite cable

Security system
Separate kitchen
Sewing machine
Stereo
Table
Tape or CD player
Toilet type
Total number of rooms
Tractor
Trash type
Truck
TV
Vacuum
VCR / DVD
Video camera
Wall material
Washing machine
Watch
Water boiler
Water disposal type
Water heater
Water pump
Water source
Wood stove